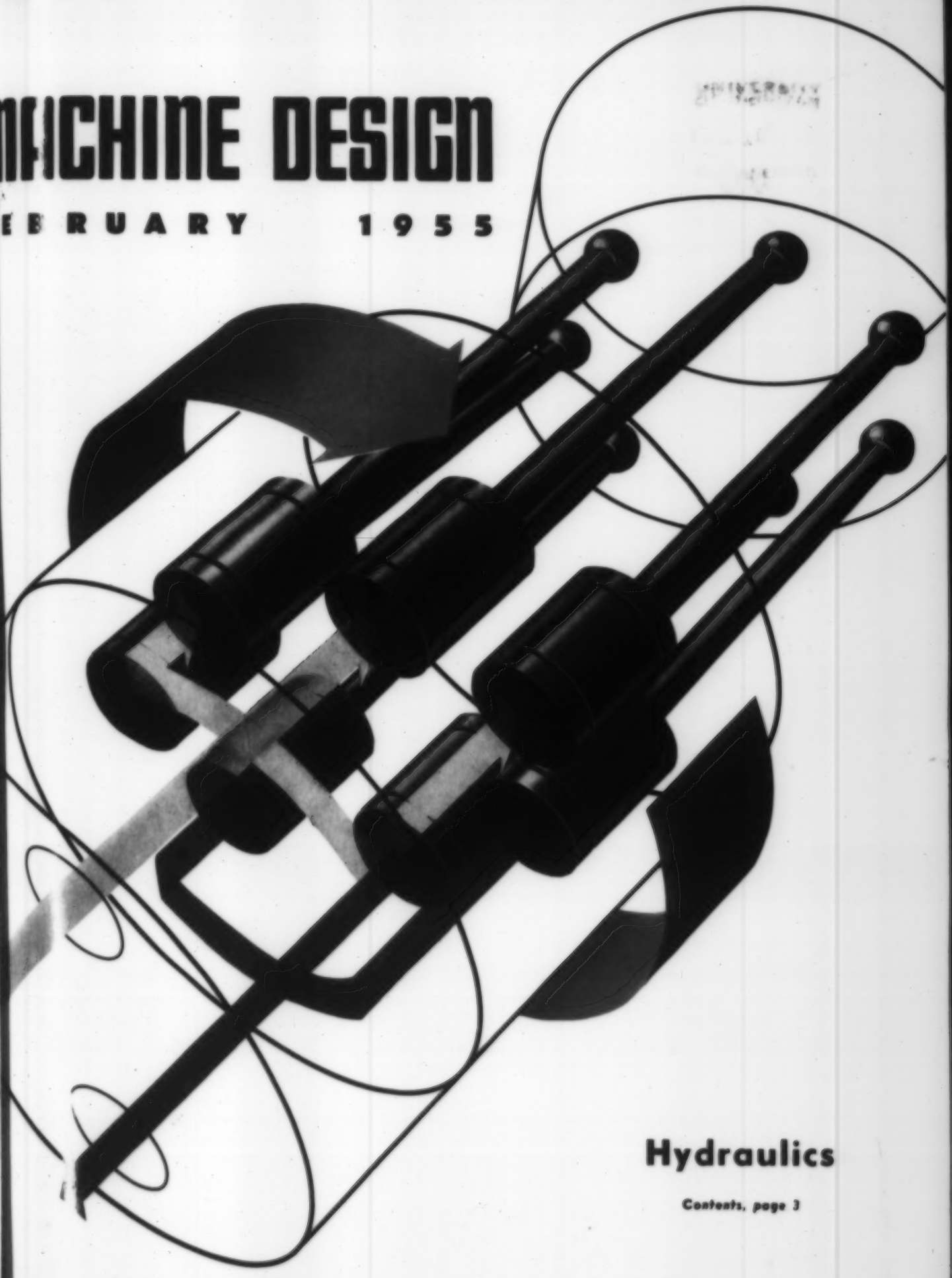
MACHINE DESIGN

FEBRUARY 1955



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CUTLER-HAMMER
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C-H

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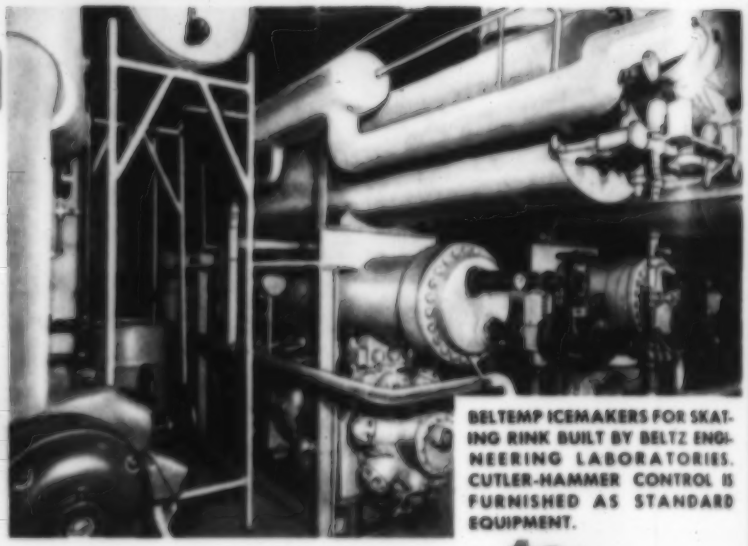

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The continued commercial success of a product is never an accident but follows as day follows night upon unceasing vigilance that ever matches product with need. And just as such scrupulous concern for the purchaser's satisfaction is never relaxed during manufacturing procedures . . . so it is intensified when the manufacturer purchases components for his product. To do less is to substitute chance for certitude. Thus, machinery manufacturers on their way up or at the top never risk machine performance on untested motor control. The majority of them insist on Cutler-Hammer Motor Control. They *know* where Cutler-Hammer Control has stood during the past 60 years. They *know* that nothing is more disastrous than the failure of any part, that nothing succeeds like success, that *no* control has been more successful than Cutler-Hammer Control . . . *your* safe selection for *any* need. CUTLER-HAMMER, Inc., 1310 St. Paul Avenue, Milwaukee 1, Wisconsin. *Associate*: Canadian Cutler-Hammer, Ltd., Toronto, Ontario.

THE PROFESSIONAL JOURNAL FOR ENGINEERS AND DESIGNERS

MACHINE DESIGN

FEBRUARY 1955
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Over the Board

Plain Talk

Bad writing seems to be a highly developed art with some engineers. An engineering editor runs across all kinds—the sentences that run on and on and on—the poorly organized report with its vital message buried in one tiny paragraph—the article that explains a very minor point in flowery technical grandeur. The best advice anyone can give on "how to write" is quoted by Air Force Major Edward Holder, in somewhat backward fashion: Engineers "should eschew verbose and esoteric philosophical multiplicities and sedulously avoid tautological profundities in communications of vital import." In other words, "use plain talk."

They Say . . .

"A technical editor must be well versed in all phrases of engineering" — R. C. RODGERS, *assistant editor*.

This Month's Cover

In case you're not familiar with the gadget on the cover, it's an axial-piston pump. Actually, the unit could be either a pump or a motor, depending on which direction it rotates. But George Farnsworth, our cover artist, seemed to like the pump, since the arrowheads look better. So a pump it is. If you want to see the article that generated the basic idea, it's the one on rotating hydraulic devices, Page 180.

Mathematical Mischief

Sometimes a reader will suggest that the mathematical expressions in our articles should be translated into "plain English." Now comes M. S. Corrington, in *Proceedings of the IRE*, proposing to replace plain English with mathematics:

$$\int \frac{d\,(cabin)}{cabin} = \log cabin + C = houseboat$$

$$d\,(Hi\,Ho) = Hi\,d\,Ho + Ho\,d\,Hi$$

We don't see much future for this sort of translation. And we most definitely disapprove of recent attempts to reduce feminine pulchritude to a mathematical formula. Mechanical engineering students at Washington University in St. Louis did just that in selecting the "Queen of Steam" for their annual dance. Here it is:

$$A\left(B + D + \frac{1}{S}\right)$$

where A = appeal (bust/waist), in./in.; B = bulk (height/weight), in./lb; D = depreciation (age/hip size), years/in.; and S = shoe size. By this formula Gina Lolobrigida comes out 2.115. We prefer the actual figure.

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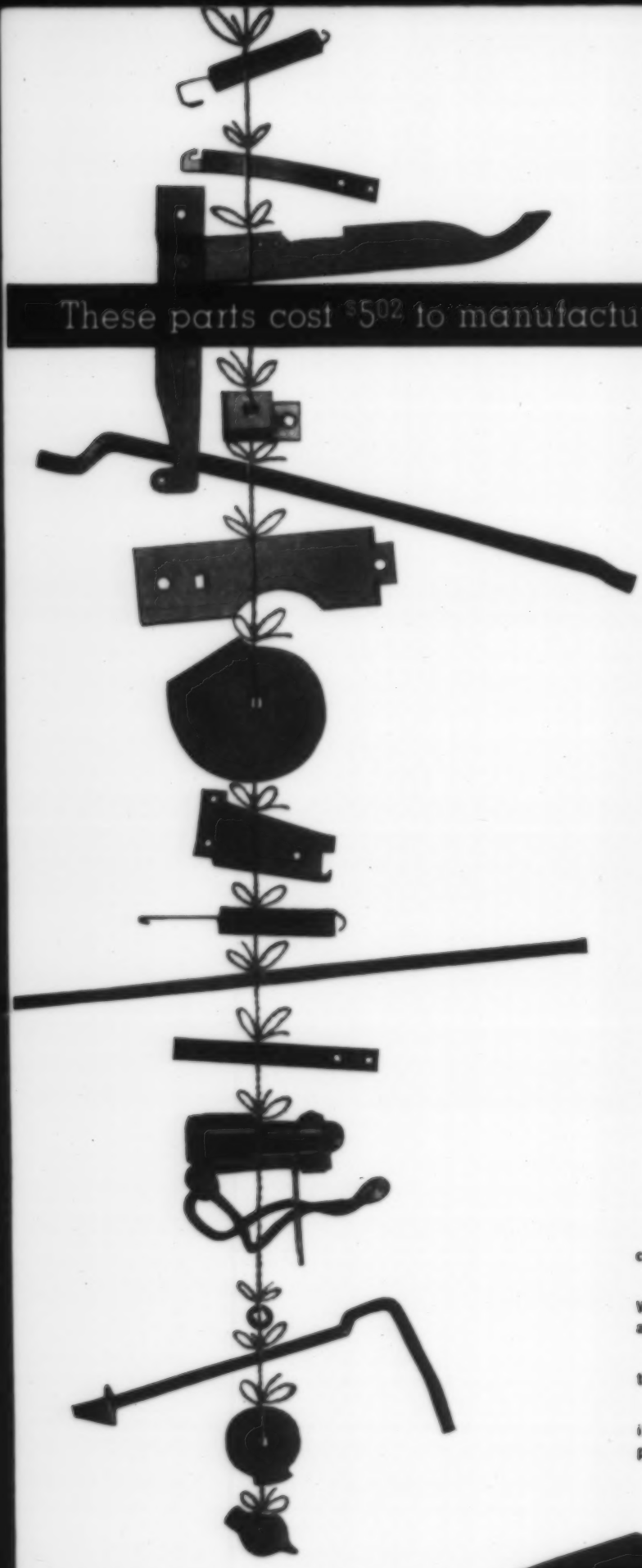

These parts cost $5.02 to manufacture and assemble . . .

This Stemco thermostat costs only 46¢ and does the job better...

If thermostatic control costs have you tied in knots, you'll be interested in th cutting case history.

Parts shown at the left were used to control temperature in a well-known wat Worked reasonably well, too. But, the 31 manufacturing and 4 plating operatio approximately $2.37 per set; assembly and calibration added another $2.65.

Stevens engineers analyzed the product, suggested using the compact Stemco thermostat—which costs only 46¢ and mounts with a single rivet.

And there are other advantages to using Stemco thermostats: you don't tie up in inventory, tooling, or special production equipment. If temperature control problem, contact Stevens for the answer.

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Stevens makes thermostats used in leading makes of:
Roasters • Fry Kettles • Vaporizers • Flat Irons • Butter Warmers • Refrigerators • Water Tanks • Waffle Irons • Percolators • Steam Irons • Sterilizers • Rectifier Pans • Electronic and Avionic Devices.

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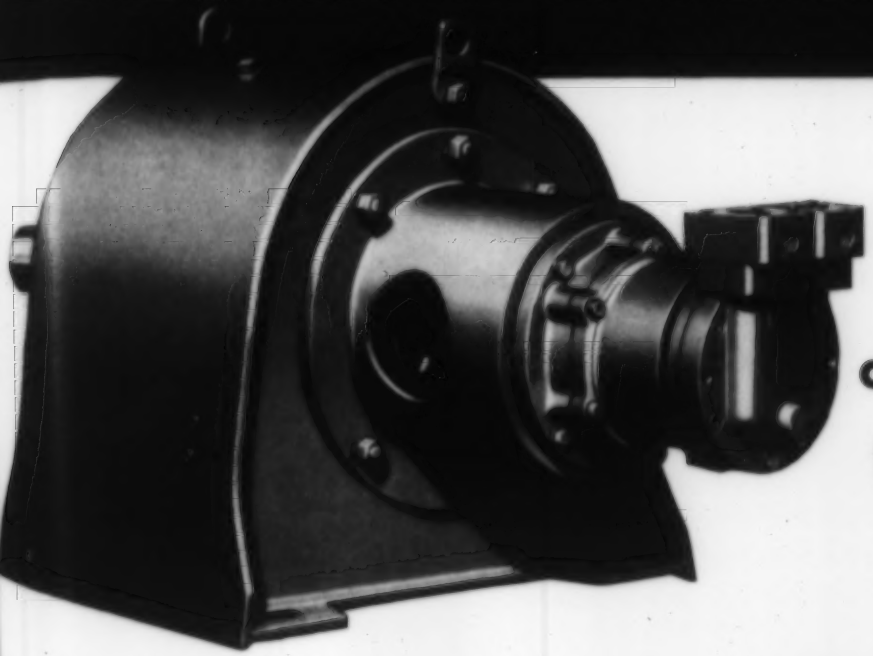
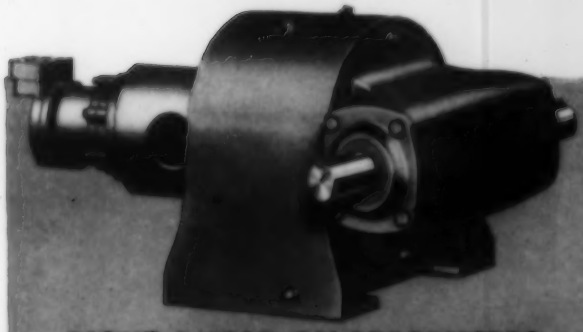


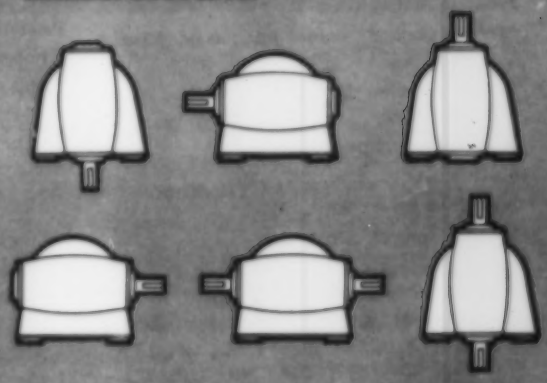
Offering for the first time compact, packaged, fluid power output drive units!

● Oilgearducers are new integral output drive units combining Oilgear Fluid Power axial piston motors and Falk All-Steel Reducers. There are horizontal and vertical models, concentric and right angle types and single, double, triple and quadruple reduction. Now, for the first time you can get a complete, easy to install, "ANY-SPEED" output unit for your high torque, low maximum speed drives. When used in combination with Oilgear Fluid Power Pumps, these reversible Oilgearducers provide infinite variability of speed, absolutely controlled rate of acceleration and deceleration, smooth and swift reversal, cushioned braking. All these together with major economies in motor, circuitry and power requirements. This new Oilgearducer "Any-Speed" output unit is available in sizes from 1 to 20 h.p. It is unequalled for applications as diverse as can-filling, paper machines, centrifugals, cable wrappers . . . and in automation or feed back applications where synchronization is an absolute necessity. Write now for new bulletin 56610. THE OILGEAR COMPANY, 1568 West Pierce Street, Milwaukee 4, Wisconsin.



RIGHT ANGLE OILGEARDUCERS

Oilgearducers with right angle output shafts are available in ratios ranging from 5 to 1500:1. In assemblies shown below.



Write for this new Bulletin 56610

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PIONEERS...NOW THREE PLANTS FOR FLUID POWER

PUMPS, MOTORS, TRANSMISSIONS, CYLINDERS & VALVES

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NEW DEPARTURES OF TOMORROW

Today, New Departure *ball* bearings are used by 14 leading manufacturers of washers and driers. Wherever there's a moving part, New Departures assure accuracy, low upkeep, longer life.

Maybe it's hard to imagine a home laundry that washes, dries, irons, folds. But it's even harder to imagine this wonder—or any other—working without *ball* bearings . . . New Departures.

In fact, New Departure *ball* bearings play an important role in just about every product with moving parts. For more than 50 years, manufacturers everywhere have counted on New Departure for bearings.

Why this confidence? It's a matter of living up to a name. It means being *first* with new departures—like the Sealed-for-Life *ball* bearing. And New Departure will be ready tomorrow with the *finest* bearings . . . *first!*

NEW DEPARTURE • DIVISION OF GENERAL MOTORS • BRISTOL, CONNECTICUT

NEW DEPARTURE
BALL BEARINGS

NOTHING ROLLS LIKE A BALL

Engineering News Roundup

Four-Jet Seaplane Ready for First Tests

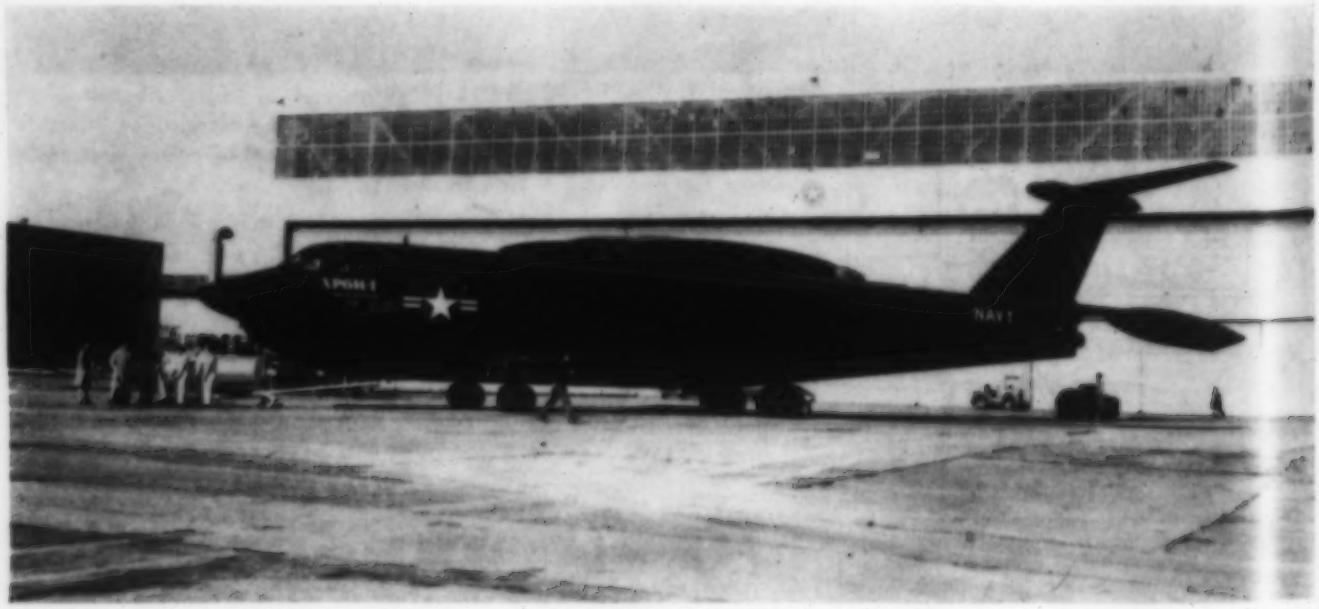
Four turbojet engines will power the SeaMaster, a new Navy attack seaplane said to be the first multijet seaplane in the world. Built by Martin Aircraft, the plane will begin flight tests in the near future.

Designated the XP6M-1, the seaplane is designed for speeds over 600 mph. Its normal cruising altitude is expected to be about 40,000 ft. Two sets of Allison J-71 jet engines are arranged on the wing on either side of the fuselage. Engines are equipped with take-off afterburners, and the entire engine assembly is mounted for easy accessibility to permit engine changes while the plane is afloat.

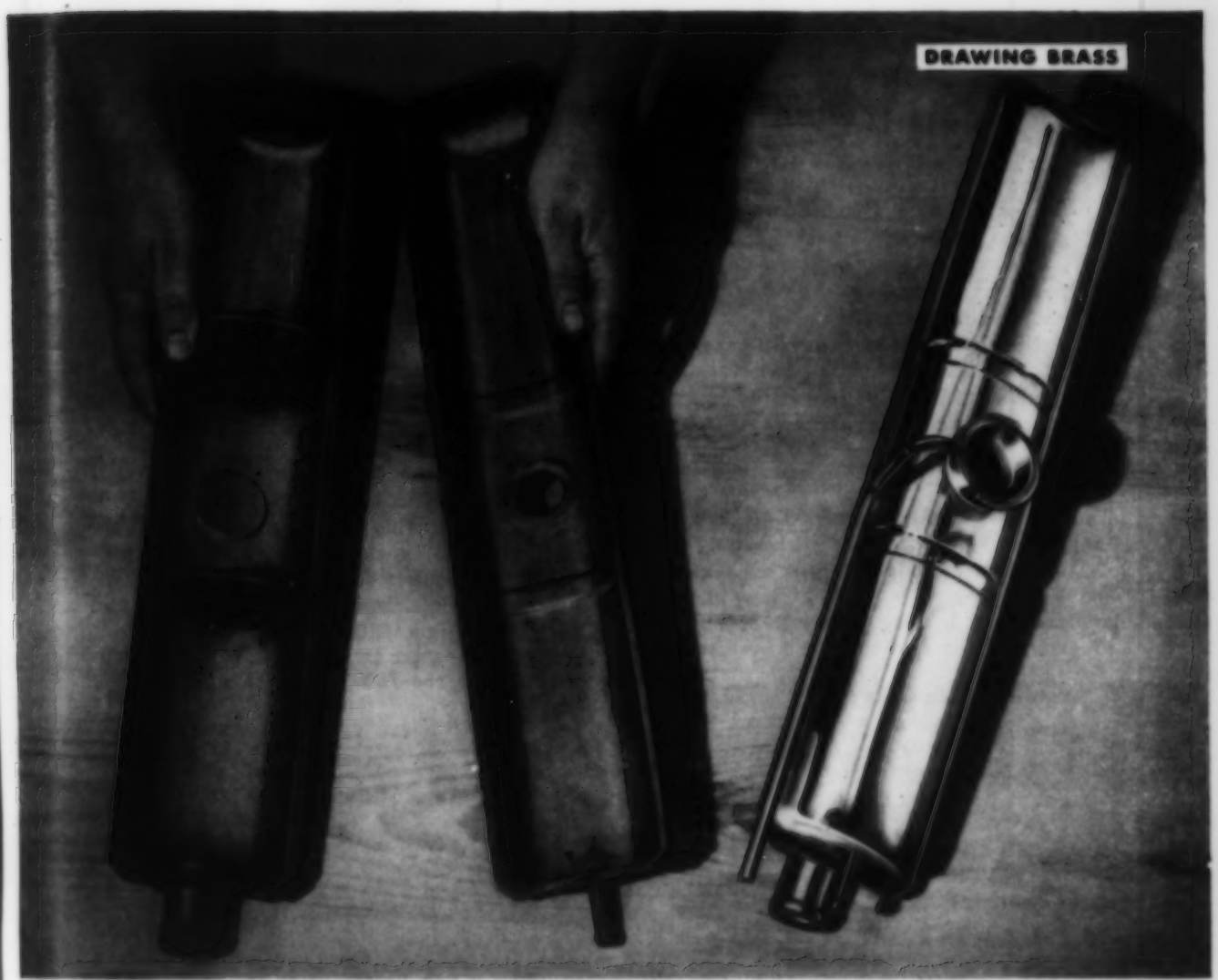
Fuel tanks are sealed in the wings. Plastic floats at the wingtips are designed to provide wingtip buoyancy when the SeaMaster is in rough water. The tail assembly is about 3 stories above the wing level to reduce possible spray damage to the control surfaces.

Five crew members are carried in a pressurized section of the cabin. When flying at 50,000 ft, the cabin can be held at a pressure equivalent to an altitude of 21,000 ft. An ejection seat is provided for emergency escape of the pilot. Other crew members use an escape chute that extends down through the bottom of the hull. A newly designed watertight rotary bomb door is sealed by a self-sealing pneumatic tube system. Inside is the mine bay which can be loaded from the top of the hull.

Photo-reconnaissance and mine laying are expected to be the major jobs of the new plane. Its mobility as a water-based aircraft promise it a significant place in future naval strategy.



World's first multijet seaplane built for the Navy by Martin Aircraft is expected to fly at altitudes of 40,000 ft at speeds over 600 mph. Carrying a crew of five, the plane will be used for mine laying and photo-reconnaissance. It has been designed for operation independent of fixed installations over long periods of time



RADIATOR TANK made of Formbrite shown before polishing and after chromium plating. Halves are assembled with a lock seam and soldered together with baffles inside. Intake spout, overflow tube and connecting fitting are also attached.

New fine-grain drawing brass cuts rejects from 13% to under 1%

These radiator tanks—used in a leading sports car—were first made of ordinary drawing brass.

But Morrison Steel Products Company, Buffalo, N. Y., found this brass wasn't stiff enough after forming. During handling, polishing and plating, many dents and nicks appeared on the surface. Rejects ran at about 13%.

Then Morrison turned to Formbrite® — Anaconda's new fine-grain drawing brass. Here's what happened.

1. Rejects dropped to less than 1%.
2. Appearance of the final plated tank (very important in a sports car) was so much improved that now Formbrite is specified for all these tanks.
3. Polishing costs were sliced almost in half.

WHY MORRISON FOUND FORMBRITE BETTER, CHEAPER TO USE

Formbrite has a superfine grain. Produced by special methods of rolling and annealing, this grain is *so fine* that often a simple color buff brings it to a bright, lustrous finish. (Compare magnification of Formbrite Drawing Brass with that of ordinary drawing brass. At right.)

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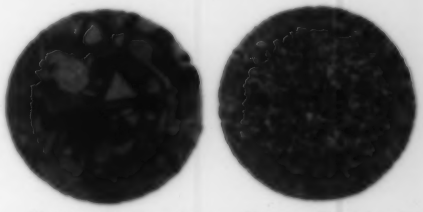

75x magnification of ordinary drawing brass.

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Rounding Up the 1955 Automobiles—2

An overhead valve V-8 engine makes its first appearance on another of the low-priced three in 1955. Plymouth boasts increased horsepower with its new Hy-Fire V-8. Completely restyled, the entire Chrysler line seems to have made the most radical change over last year's models. One notable Chrysler change is the removal of the automatic shift control lever from the steering column to the instrument panel.

Buick has redesigned its grille, giving a somewhat lighter appearance to the front end. Oldsmobile, a hot item in 1954 stylewise, made few changes this year in an effort to maintain its standing.

American Motor's Rambler will be marketed by both Hudson and Nash dealers as their "basic volume car."

Rambler

Horsepower rating of the Rambler L-head 6 engine was not increased this year. Essentially the same as the 1954 engine, it prides itself on economy of operation. A new front fender design incorporates full-wheel cutouts. A turning diameter of 36 feet for the two-door series is said to be the best among

Engine Specifications

Type	L-head, in-line
No. cyls.	6
Bore & stroke (in.)	3⅛ x 4¼
Displ. (in.³)	195.6
Comp. ratio	7.3 to 1
Bhp, max	90 @ 3800
Torque (lb-ft)	150 @ 1600

Size and Weight

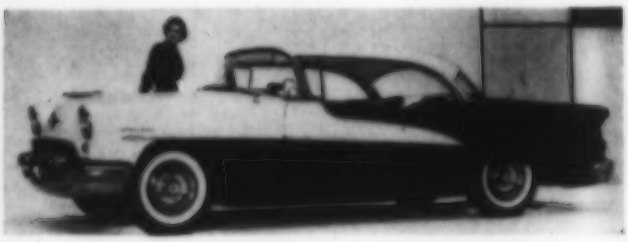
	2-door	4-door
Wheelbase (in.)	100	108
Length (in.)	178¼	186¼
Width (in.)	73½	73½
Height (in.)	59⅝	59⅝
Weight (lb)	2515*	2630*

*Estimated

U. S. production cars. A new grille consists of a single die casting. Either a Hudson or a Nash medallion will be mounted in the center of the grille, depending on which dealer is selling the car. Reclining seats and the "Twin Travel Bed" are available as optional equipment on the four-door Ramblers. Air conditioning is offered as a factory-installed option on all models. Tubeless tires are standard equipment. Three transmissions are available—conventional, overdrive and Dual-Range Hydra-Matic.

Oldsmobile

Oldsmobile's "Rocket" engine, now in its seventh year of production, incorporates many engineering improvements for 1955. Among these are a newly designed combustion chamber and a new high-lift camshaft. All this adds up to a top horsepower rating of 202 in the Super "88" and "98" series. Sweep-cut front fenders have been adopted by all three Oldsmobile lines ("88," Super "88," and "98") this year. The Olds two-tone color styling that proved so popular in 1954 has been continued; side molding for the color separation is stainless steel.



Engine Specifications

	"88"	Super "88" and "98"
Type	OHV, Vee	OHV, Vee
No. cyls.	8	8
Bore & stroke (in.)	3⅛ x 3 7/8	3⅛ x 3 7/8
Displ. (in.³)	324	324
Comp. ratio	8.5 to 1	8.5 to 1
Bhp, max	185 @ 4000	202 @ 4000
Torque, max (lb-ft)	320 @ 2000	332 @ 2400

Size and Weight

	"88" Series	"98" Series
Wheelbase (in.)	122	126
Length (in.)	203.36	212.36
Width (in.)	77.8	77.8
Height (in.)	60.5	59.3*
Weight (lb)	3900	4030

*Holiday series.

Over 100 body color combinations are available. Improvements have been made in riding quality through a redesigned shock absorber mounting. Steering effort is said to be reduced by using needle bearings on the steering pitman arm shaft. A completely redesigned air-conditioning system is more compact and more efficient. Tubeless tires, of course, are standard equipment on all the 1955 models. The automatic headlight dimmer is continued as an option.

Dodge

Dodge offers three series this year, the Custom Royal, Royal and Coronet. All models have an increased wheelbase of 120 inches, and overall length has been increased 16 inches on some models. Wider

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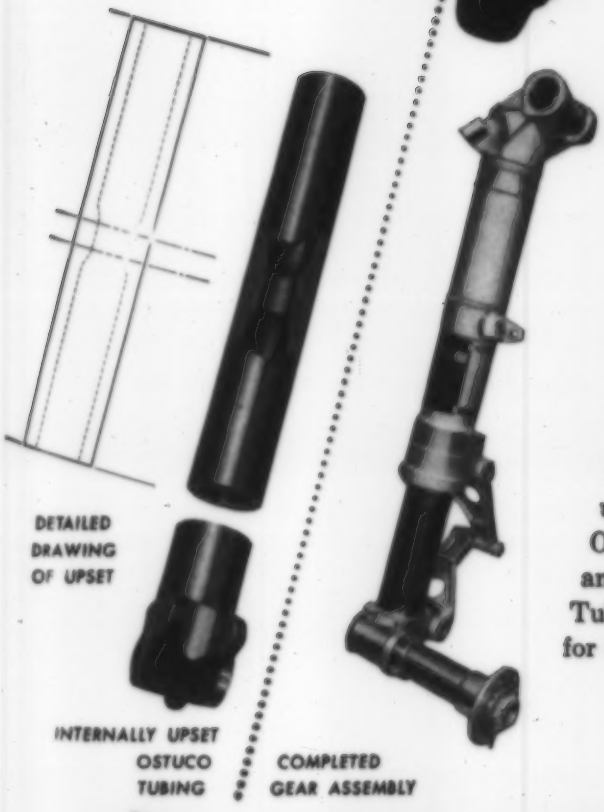
Saves $4.95 per unit



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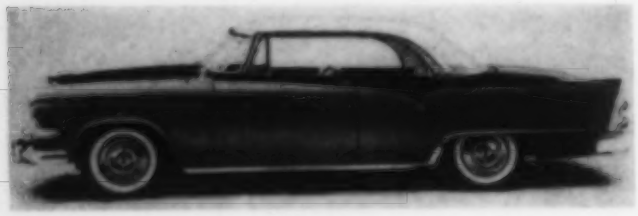
doors and flared rear wheel openings add to the lower, longer look. Trunk space has been increased to 37.6 cubic feet with the spare tire installed. Three engines, two V-8's and a 6, comprise the power line-up for Dodge for 1955. A new short-stroke overhead-valve Red Ram V-8 with a compression ratio of 7.6 to 1 is rated at 175 hp. The Custom Royal series incorporate a Super Red Ram V-8 of 183 hp.



Engine Specifications

	Get-Away 6	Red Ram	Super Red Ram
Type	L-head, in-line	OHV, Vee	OHV, Vee
No. cyls.	6	8	8
Bore & stroke (in.)	3.25 x 4.63	3.63 x 3.256	3.63 x 3.256
Displ. (in.³)	230	270	270
Comp. ratio	7.4 to 1	7.6 to 1	7.6 to 1
Bhp, max	123 @ 3600	175 @ 4400	183 @ 4400
Torque, max (lb-ft)	194 @ 1600	240 @ 2400	245 @ 2400

Size and Weight

Wheelbase (in.)	120
Length (in.)	212.1
Width (in.)	74.5
Weight (lb)	3475*

*Royal Sedan with V-8 engine and Powerflite.

With a four-barreled carburetor and dual exhausts, it develops 193 hp. Other features of the V-8's are a single rocker shaft and rigid, lightweight rocker arms. Gearshift for the automatic transmission has been moved to the dash just to the right of the steering column. New Chrysler-designed coaxial power steering is also available on the 1955 Dodges.

Buick

Buick for 1955 features a new variable-pitch dynaflow transmission. During normal driving, the Dynaflow works the same as before. For fast acceleration, the driver presses the accelerator to the floor, changing the angle of the stator vanes. All this results in better performance, Buick says, because engine rpm can be increased to the point where the engine is operating near maximum torque. Horsepower

ratings have been increased for both the Super and Special series engines. Rating of the Super series

Engine Specifications

	Special	Super
Type	OHV, Vee	OHV, Vee
No. cyls.	8	8
Bore & stroke (in.)	3.625 x 3.2	4.0 x 3.20
Displ. (in.³)	264	322
Comp. ratio	8.4 to 1	9 to 1
Bhp, max	188 @4800	236 @ 4800
Torque, max (lb-ft)	256 @ 2400	330 @ 3000

Size and Weight

	Series 40 and 60	Series 50 and 70
Wheelbase (in.)	122	127
Length (in.)	206.7	216.0
Width (in.)	76.2	80.0
Height (in.)	60.6	62.7
Weight (lb)	3807	4278

engine, used in the Super and Roadmaster series cars, has been increased to 236 hp. A four-barrel carburetor is used for the first time. Horsepower of the Special engine used in the Special and Century series has been stepped up to 188. Compression ratio of the Super engines is now 9 to 1, among the highest in the industry. In the Special series, compression ratio has been increased to 8.4 to 1. Power steering is now standard on both the Roadmaster and the Super and optional on all other models. Grille, headlight visors and bumpers have been given a new look. Two-tone and three-tone color combinations are available this year.

DeSoto

DeSoto features two restyled lines for 1955, the Firedome and Fireflite. Both are powered by overhead-valve V-8 engines featuring the hemispherical combustion chamber. Equipped with a new four-barrel carburetor, the Fireflite engine is rated at 200 hp. Increased by 15 horsepower over last year's engine, the Firedome is now rated at 185 hp. Both

Engine Specifications

	Firedome	Fireflite
Type	OHV, Vee	OHV, Vee
No. cyls.	8	8
Bore & stroke (in.)	3.72 x 3.344	3.72 x 3.344
Displ. (in.³)	291	291
Comp. ratio	7.5 to 1	7.5 to 1
Bhp, max	185 @4400	200 @ 4400
Torque, max (lb-ft)	245 @ 2800	274 @ 2800

Size and Weight

	Firedome	Fireflight
Wheelbase (in.)	126	126
Length (in.)	217.9	217.9
Width (in.)	78.3	78.3
Height (in.)	60.6	60.6
Weight (lb)	3900	3970

engines are designed to operate on standard fuels. Wrap-around windshield increases the glass area over 20 per cent. Improved Powerflite automatic trans-

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BEARINGS AND PARTS

mission has its control lever mounted on the instrument panel. Full-time coaxial power steering, improved air conditioning with an automatic disconnect clutch, and a new fast idle control when the engine is idling in neutral, are among the many options available.

Plymouth

Plymouth is completely restyled for 1955. Bodies have been made lower, longer and wider and engines feature increased horsepower. A new 6-cylinder engine has a higher compression ratio and features a new all-aluminum carburetor with integral automatic choke incorporating a heat retainer plate to match choke operation to engine temperature. A choice of two V-8 engines is offered on all three Plymouth lines with an optional power package that is said to boost horsepower to a top of 177 at 4400 rpm. Both V-8's have overhead valves with hydraulic valve lifters. The V-8's also have a new combustion chamber called a polysphere. By placing the exhaust valve seat in a polygonal section of the chamber, better engine breathing and less loss of heat energy is claimed over the older designs. Plymouth's standard transmission is available with or without overdrive. PowerFlite, the fully automatic transmission, is available on any of the Plymouth lines with any of the engines. The PowerFlite control lever is now located on the instrument panel. Tubeless tires are standard equipment. Solex tinted glass and air conditioning are among the many extras available.

(*To be concluded in March*)

Engine Specifications

	PowerBow Six	Hy-Fire V-8	
Type	L-head, in-line	OHV, Vee	
No. cyls.	6	8	
Bore & stroke (in.)	3.2544.63	3.44 x 3.25	3.563 x 3.25
Displ. (in.³)	230	241	280
Comp. ratio	7.4 to 1	7.6 to 1	
Bhp, max	117 @ 3600	157 @ 4400	167 @ 4400*
Torque, max (lb-ft)	194 @ 1600	217 @ 2400	231 @ 2400

*177 @ 4400 with optional power package.

Size and Weight

Wheelbase (in.)	115
Length (in.)	203.8
Width (in.)	74.6
Height (in.)	60.1
Weight (lb)	3297*

*Belvedere sedan with V-8 engine and Powerflite.

Librarians Learn to Help Designers Look It Up

Design engineers may benefit indirectly from a new course to be given by the Columbia University School of Library Service. Librarians having problems with engineering or engineering literature will evaluate and survey library resources in engineering and physical sciences. In the course, which starts July 5, they will learn methods of obtaining house organs, trade journals, press releases and government reports.

Purpose of this course, said to be the first of its kind ever given, is to acquaint librarians with engineering literature. Librarians in charge of engineering libraries will find it less difficult to provide designers with the type of information most valuable in their work.

William S. Thomas, Vice President, Emmaus Foundry and Machine Co. Inc. Emmaus, Pa., won first prize of $500 in the Gray Iron Founders' Society Redesign Contest for 1954. The contest is conducted annually by the Society for the best example of products redesigned for production in gray iron.

Previews

How to Stretch Time

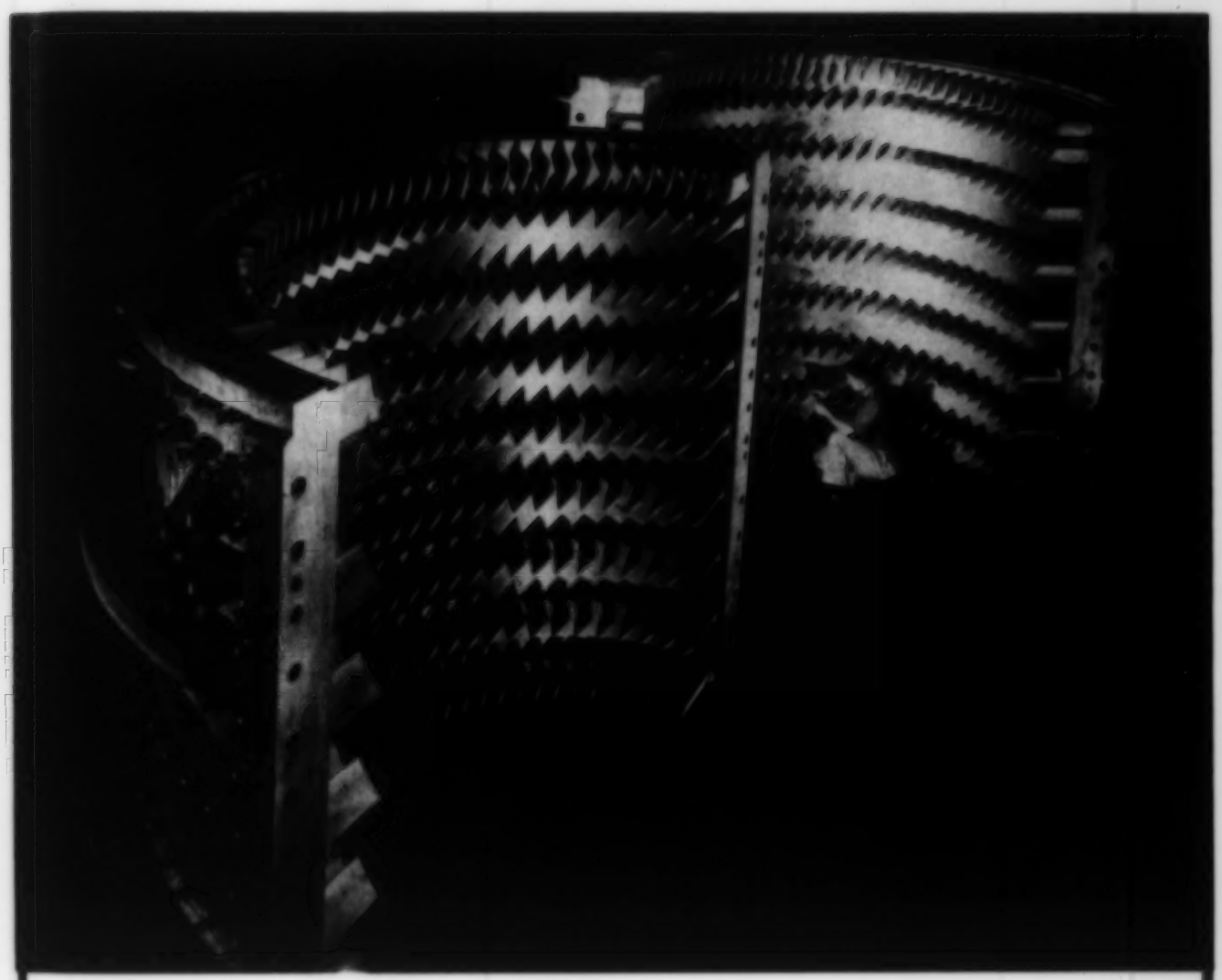
Motion so fast that it's a blur to the eye can be stopped cold with high-speed photography—a technique that holds much promise in development engineering work. Up to 8000 pictures per second can be taken with the techniques outlined on Page 150, a speed that would slow down a 3600-rpm synchronous motor to a lazy one turn every 9 seconds. If you were able to photograph a whole day's operation at this speed, the resulting movie film would run continuously for almost a year and a half.

Spinning Liquids

In a rotating hydraulic unit, centrifugal pressure of the hydraulic fluid can play hob with the most carefully calculated system pressures. As the article on Page 180 points out, added pressures can be as much as ten tons in a torque converter. These additional pressures are often a factor to be considered carefully in design.

Bearing Up

Having high load-carrying capacity, aluminum bearings have been used successfully in automotive and other applications. Since aluminum bearings are relatively new, as the article on Page 189 points out, care is needed in developing a new design. But solid aluminum and aluminum-on-steel bearings have certain advantages which may be worth investigating.



GIANT COMPRESSOR using these two cylinder halves will blow air at 1 million cfm when completed. Being constructed by Allis-Chalmers Mfg. Co., the compressor is to be installed at the ram-jet addition of the Air Force's Arnold Engineering Development Center, Tullahoma, Tenn. Two of these 1 million cfm axial compressors will be installed at the test facility. Each will be driven by a 24,500-hp synchronous motor with a 6000-hp wound-rotor motor for starting and to supplement the main drive motor. Studies of jet aircraft operation at supersonic speeds and subatmospheric pressures will be possible when the ram-jet addition goes into operation

Sealed Pump Is Inside Motor

By placing a pump compressor mechanism inside its driving electric motor, designers were able to reduce the size of the unit to about one-fourth that of a conventional compressor.

Designed by Wetmore Hodges and Associates, the pump is a positive-displacement type with only two moving parts. It has no valves. Two Hill Rotoid Gears, one inside the other, maintain multiple tooth contact through a 220 degree arc to form several individual pressure chambers. Both gears are inside the stator core.

To make the unit a true pressure vessel, the stator windings had to be enclosed and sealed. Shell Chemical Corp.'s Epon, an epoxy resin, provided the sealing means. The resulting assembly is said to be mechanically strong, chemically resistant and has high dielectric properties. Tests show the unit to be completely leaktight up to 350 psi at temperatures between −20 and 250 F. It is expected to find its greatest use in household or commercial air conditioning or refrigerating applications where small size is important.

New addition to the aluminum rolling equipment at Aluminum Company of America's Davenport works is being installed. Construction has started on a 100-inch cold

(*Continued on Page 24*)

Reduce Weight by 28%
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Whenever *weight* is the problem in a new V-Belt drive design, then Dayton Cog-Belts are the *solution*. You can eliminate costly, unnecessary weight by as much as 28% without sacrificing one ounce of power, impairing efficiency or shortening life of the drive! How? Dayton Cog-Belts deliver 40% more horsepower per belt from the power source. Therefore, you can specify narrower, shorter sheaves with less grooves . . . shorter and fewer belts . . . shorter center distances . . . and lighter supporting frame members for a given power application. And in addition to saving weight, you save space and cost and gain compactness and power.

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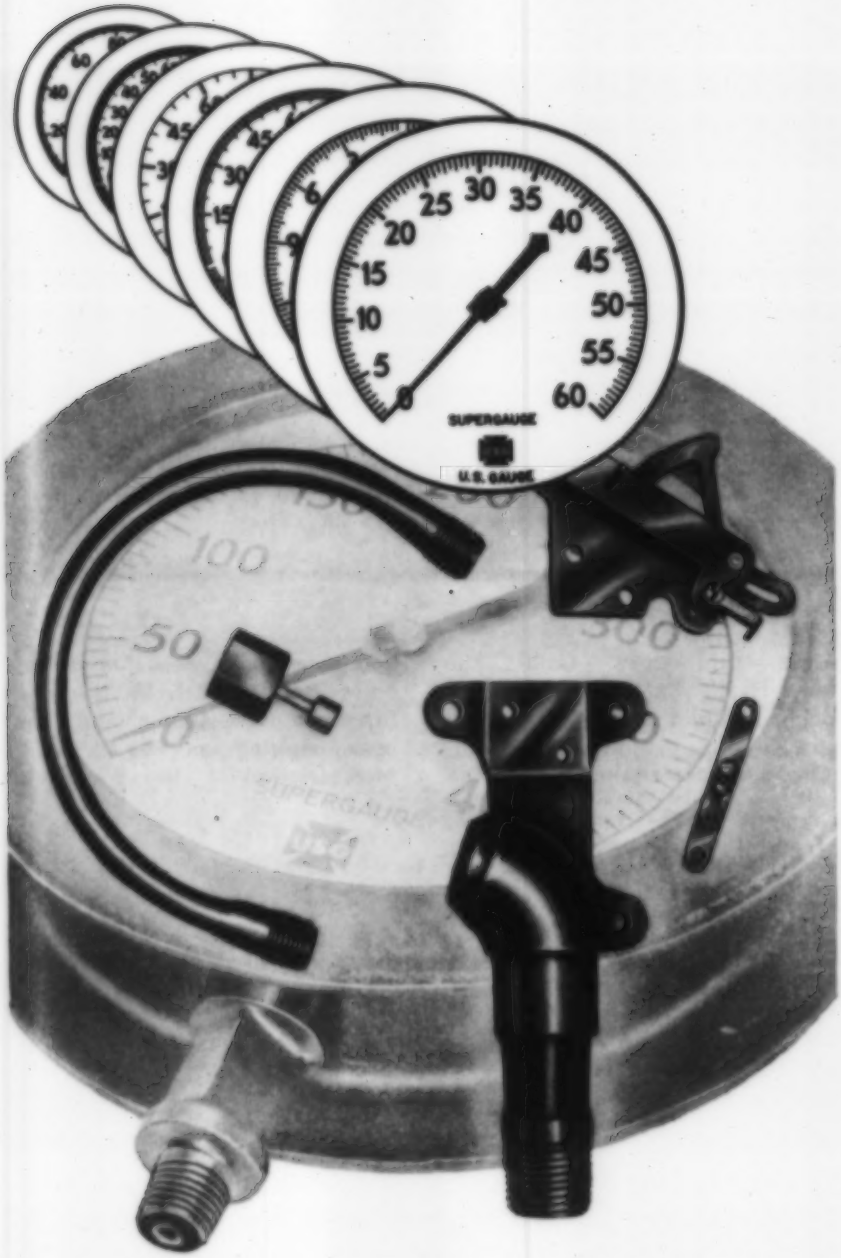

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Above, a portion of USG's Research Laboratory. Here constant testing of materials under customer operating conditions assures optimum efficiency and long gauge life.

(Continued from Page 21)

mill for finish rolling wide aluminum coiled sheet, used in the field of aluminum-clad buildings, as well as in the aircraft and other transportation industries. The new 100-inch mill is expected to be in operation early in 1956. Alcoa will then be able to produce substantially wider cold-finished coiled sheet than has ever been available before.

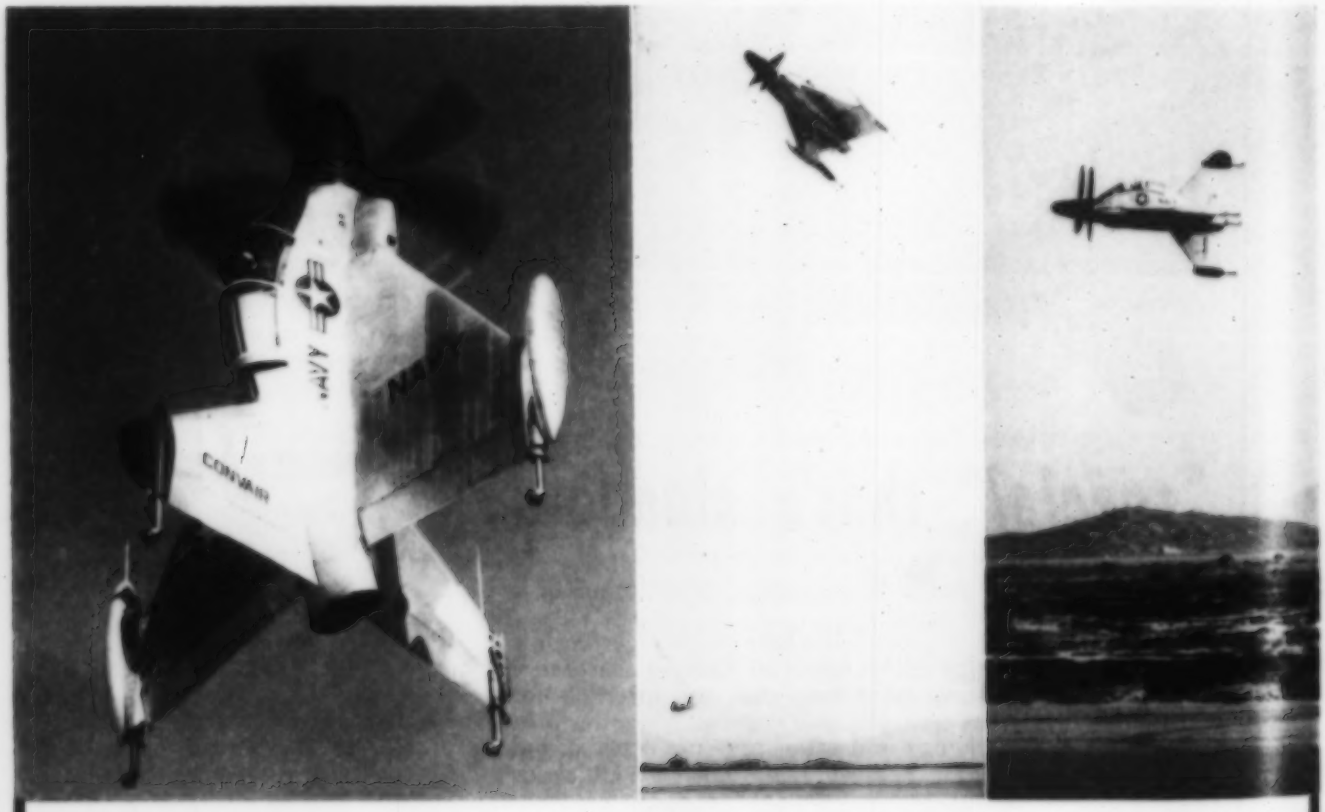
NO OVERHEAD: This underground diesel-electric locomotive is about as high as an automobile. It is 47 feet long and 7 feet wide. Built by General Electric, it travels at 37.5 mph and is reported capable of pulling 800 to 1000 tons. In use at the U. S. Potash mine, the 420-hp machine had to be dismantled to get it underground, then reassembled in the mine

New Shoes Promise Smooth Stops

Railroad brake shoes made of a composition material are being tested as a possible replacement for steel shoes in railway service.

A joint project of Westinghouse Air Brake Co. and Johns-Manville Corp., the new development promises smoother subway car and passenger train stops. Called the Cobra Brake Shoe, the device is said to be quiet and promises long mileage life.

Because cars equipped with the new shoes have been found to require only one-fourth the brake force now used, simpler and lighter brake rigging may be used. Uniform friction of the shoe against



UP AND OVER: So goes the "Pogo" in a recent test at San Diego. Built for the Navy by Convair, this XFY-1 is said to be the world's first successful vertical rising airplane (MACHINE DESIGN, September, 1954, page 21). In this test, the plane was leveled at an altitude of less than 200 feet. After flying horizontally for about 20 minutes, the XFY-1 was nosed up at about a 50-foot altitude and backed down to a landing on a 50-foot diameter concrete mat

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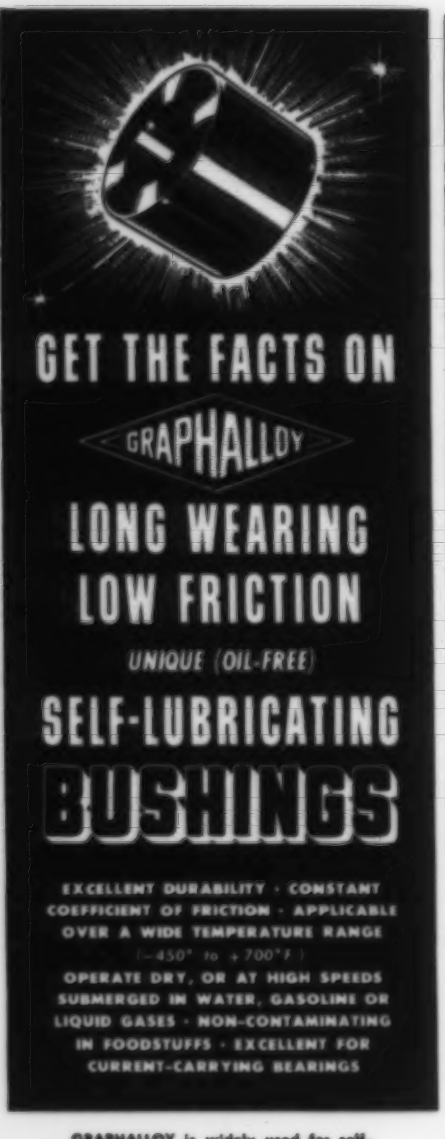

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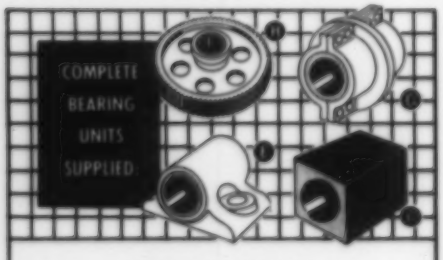

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News Roundup

the wheel is said to minimize lurching at the end of a stop. It performs equally well in wet or dry weather, according to its designers.

Weight has been reduced to one-half as much as present type brake shoes. Damage due to thermal cracking from high-speed braking duty is expected to be reduced.

• • • FAR-AWAY BLUEPRINTS *may be read easily with RCA's "TV Eye", a closed-circuit television system. Good two-way visual communication between separated buildings is said to be possible with the system. All the designer has to do is hold up the drawing and let the camera relay the information to a TV receiver in the shop. It could be very handy when it's time to make that nineteenth production change.*

Etching Process Makes Stampings Without Stampings

Sheet-metal stampings can be made without mechanical dies to reduce some of the costs involved in conventional methods. Chemical etching substitutes for drilling, routing and blanking or piercing in a process used by Chance Vought Aircraft Inc.

The method, called "Chemi-Cut," works on the photoengraving principle. First, a black-and-white master drawing is made of the part. Then, the drawing is transferred to the metal by photo engraving, metal lithographing, or silk-screen printing. A specially developed acid-resisting ink is used. Unwanted material is etched away by acid and the desired part remains.

One application in which the process was used to advantage was making screen assemblies. By the former method, 216 spot welds had to be made. Chance Vought designers redesigned the screen by making a stainless steel strip with the holes all cut out. The strip required no operations other than the etching to make it usable. Time from making the drawing to the first finished part was said to be less than 3 hours.

Maximum size of parts present-

For concentrated
HEAT
for confined areas

CHROMALOX
Electric
CARTRIDGE HEATERS

SAFE • EFFICIENT
EASY-TO-INSTALL

Chromalox Electric Cartridge Heaters provide dependable heat when and where you need it at the temperatures you require. Dies, molds, platens, moving parts, etc are quickly and accurately heated to controlled temperatures required for most efficient production. Lengths up to 40", diameters ⅛" to 3½", ratings 30 to 8750 watts.

A-4420

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CHROMALOX
THE BEST IN ELECTRIC HEAT

ly being produced by the "Chemi-Cut" method are 27 by 30 inches. About 0.001-inch per minute can

Chemically etched air screen, left, was made in one piece and required no burring, drilling or welding. The air screen, right, made by conventional methods, required 216 spot welds

be etched at normal temperatures. Parts up to 0.006-inch thick can be made with a vertical edge.

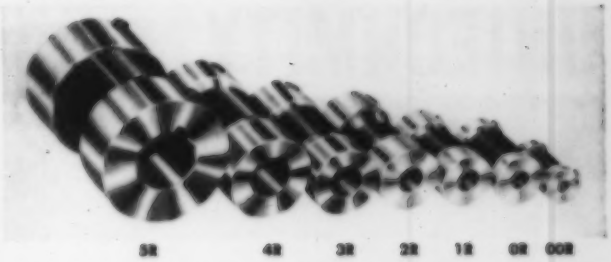
Some of the metals that can be etched in this way, according to the company, are aluminum, copper, bronze, brass, steel, beryllium, titanium and chrome-plated sheet stock. Physical properties of the materials are not affected.

1954 Censuses of Business, Manufactures and Mineral Industries will be conducted by the Bureau of Census this year. These censuses will involve collection of basic information regarding 1954 business operations of more than 3 million stores, factories and mining establishments. Emphasis is being placed upon accuracy and prompt reporting by businessmen contacted. Census figures are expected to be valuable to businesses in making decisions on plant location, product development, marketing channels, and many other matters.

New order index of industrial supplies and machinery rose stead-

"must flexibly deflect to 20° under 50 in. lbs."

specify Guardian FLEXIBLE COUPLINGS



5R 4R 3R 2R 1R 0R 00R

Freedom of the designer to select and specify the exact length which his drive requires—*plus* very low outside diameter of coupling for the load it carries—*plus* the availability of Flex-Elements to meet special drive problems like the example given here—*plus* one-piece construction in 1/15 to 3 HP series—these are reasons for more and more OEM specifications of Guardian DYNA-LINE flexible couplings.

Our Product Application Department will welcome consideration of your coupling problem. GUARDIAN—also producers of the molded nylon splined sleeve coupling.

Write for Catalog Page C-102 and Drive Data Form #53.

FROM OUR PRODUCT APPLICATION FILE

Case History No. 25-3-R

Problem: A deposit drawer for drive-in banking activates a limit switch just before reaching the extreme limit of its travel. The momentum built up by the gearhead motor imposes approximately 50 in. lbs. upon the arrested motion of the drive train. To protect the gears against this sudden shock a flexible coupling is required which will deflect flexibly 20° in rotation under this load.

Solution: A study of the load deflection involved, with the normal running torque in this drive, found its answer in one of the several Flex-Elements available in Dyna-Line couplings. The No. 3-R in 4½ inch length was then selected. No premium price for so-called "non-standard length".

Guardian PRODUCTS CORP.
COUPLING DIVISION
Dept. IC-M, 1215 E. Second St.
Michigan City, Indiana

Guardian
QUALITY IS TRUE ECONOMY

FOR LABORATORY - TOOLROOM - PRODUCTION

#704 Stewart-Warner Dynamic job-type Balancer

A basically new idea in balancing for precision, easy set-up and easy adaptability for any balancing problem.

Does both kinetic and dynamic balancing with average set-up time of less than three minutes. Capacity from half a pound to half a ton and ½" to 44" dia. Sensitivity is within 0.04 in.-oz. Model 704, price including operator training, only $3475. Other models available with greater capacities, etc.

Write for more information

Dynamic balancing a drag fread disposal unit on a Stewart-Warner 704 Electronic Balancer.

Merrill ENGINEERING LABORATORIES

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USE
ABBOTT BALLS

In any given shipment of Abbott carbon steel Bearing Balls you'll find UNIFORMITY of size tolerances and sphericity. This is because Abbott production standards are geared to meet industry's most rigid requirements. Every Abbott Bearing Ball — *Deep Hardened* and *Tempered* for maximum shock resistance and load carrying ability — is a model of precision, unsurpassed for sphericity, size tolerance, depth of case and other essentials of fine carbon steel bearing balls.

Specify Abbott . . . you can't ask for a better carbon steel ball!

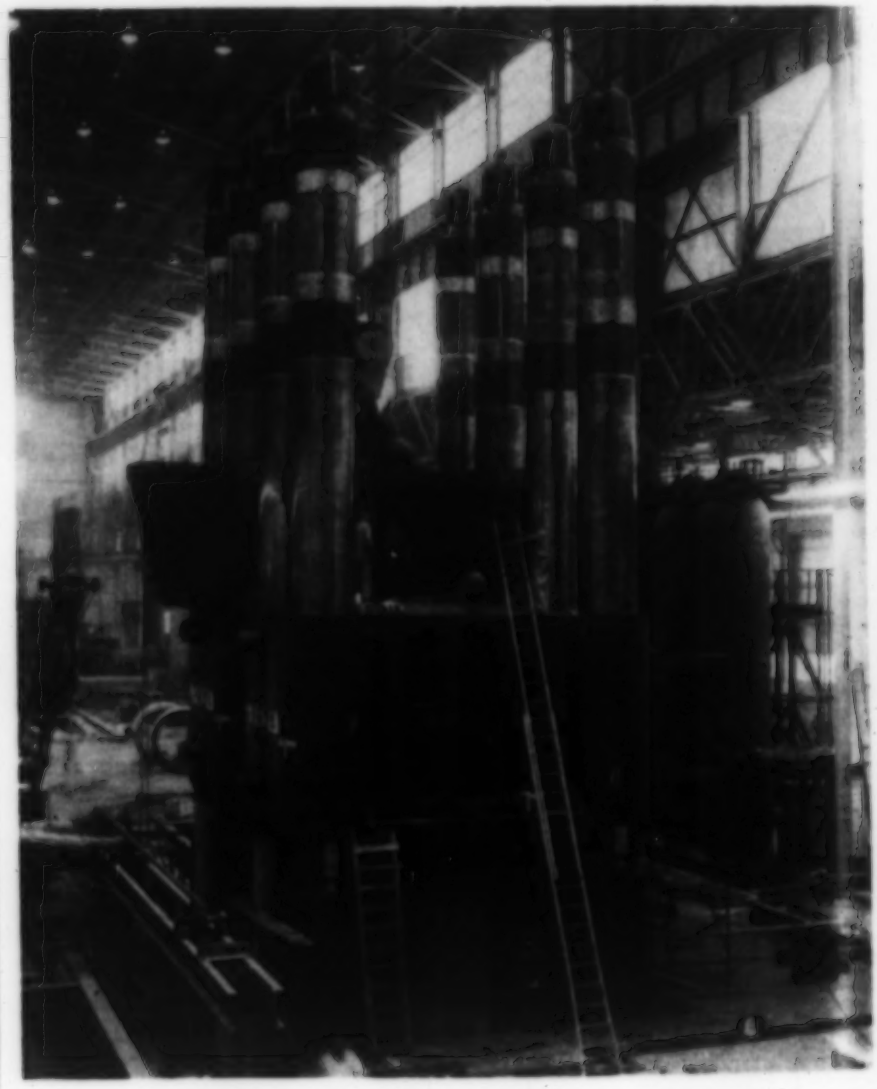
THE ABBOTT BALL CO.
50 Railroad Place, Hartford 10, Conn.

ily in November and almost equaled the year's high. The American Supply and Machinery Manufacturers' Association reports the new order index for November at 146.2. High for the year was 148.1 in September. The index measures the flow of orders received by Association members who are manufacturers of production and maintenance equipment, tools and supplies. The value of orders received during November 1954 was more than 46 per cent above the base month of July 1948.

Steel Protected with Dipped Aluminum Coat

Chemical and high-temperature corrosion of steel can be reduced by applying a thin coating of pure aluminum to steel and its alloys, a process now commercially available.

Called "Alumicoat," the process consists of dipping metal to be bonded into molten aluminum for a few minutes. A metallurgical iron-aluminum alloy bond is formed at the interface. Actually,



BIG SQUEEZE of 50,000 tons will press aluminum aircraft sections into shape when this new press goes into operation. Built by Mesta Machine Co., this huge press is being erected at Aluminum Company of America's Cleveland works.

FLEXIBLE SHAFT

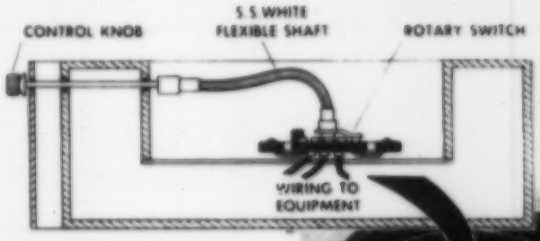
Fact and Fiction

FACT

For mechanical operation of inaccessible parts, S.S.White flexible shafts will do the job better . . .

WHY? Because S.S.White flexible shafts provide a *single, self-contained, easily applied unit* for transmitting power to drive the inaccessible parts or for providing manual control to the parts. This means fewer parts, simplified assembly, no alignment problems, and lower costs. Also, in many cases, flexible shafts can save space because they give wide latitude in locating driven or controlled parts.

EXAMPLE — Remote control for a rotary switch



In service, the rotary switch shown at right is fully enclosed inside a cylindrical column. The flexible shaft makes it possible to locate the switch in the most desirable spot while providing smooth, easy control from a convenient point. This big advantage of flexible shafts can be a lifesaver in many cases of equipment design.

FLEXIBLE SHAFT FACTS FOR DESIGNERS

BULLETIN 5306 gives basic information and data about flexible shafts and tells how to select and apply them. Write for a free copy. Address Dept. S.

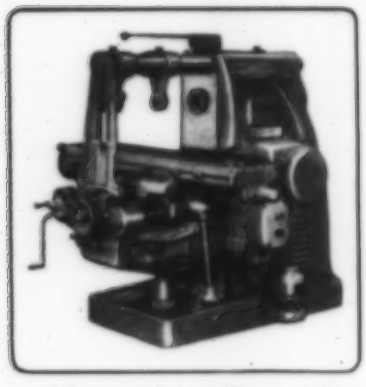
THE S.S.White INDUSTRIAL DIVISION
DENTAL MFG. CO.
10 East 40th Street
NEW YORK 16, N. Y.

Western District Office • Times Building, Long Beach, California

FICTION — Flexible Shafts Are All Alike

Actually, there's a big difference in flexible shafts — a difference which is reflected in the operation and performance of your product. S.S.White flexible shafts, which incorporate the latest technical and engineering advancements, give a positive assurance of superior service. And backing this up is a staff of experienced flexible shaft engineers who are ready to cooperate with you in working out the necessary details to insure the success of your application.

From
START
to
FINISH
Specify
RUTHMAN
GUSHER
coolant pumps



Illustrated is a Kearny & Trecker #2 Model CK Milling Machine equipped with a Gusher Coolant Pump.

From the moment you start your Ruthman Gusher Coolant Pump you get copious coolant flow. There is no priming necessary, and your Gusher Pump uses less power when throttled. Pre-lubricated ball-bearings and an electronically balanced rotating shaft assure you of low maintenance cost and trouble-free operation. Specify Gusher Pumps on your metal-working machinery.

THE **RUTHMAN** MACHINERY CO.
1811 Reading Road Cincinnati, Ohio

Everyone recognizes this as a sign of strength...

And smart gear users know this CINTI is the sign of the best in custom made gears.

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THE CINCINNATI GEAR CO. • CINCINNATI 27, OHIO

News Roundup

the aluminum penetrates the steel to a depth of about 0.0015-inch. From 0.0005 to 0.001-inch of aluminum coats the outside of the piece. Thickness of the coating depends upon the type of material and the time of immersion.

Developed by General Motors Research Laboratories (see MACHINE DESIGN, August, 1952, Page 244), the process is now commercially available through the facilities of Arthur Tickle Engineering Works Inc.

It has been found that high-temperature oxidation of mild or low-alloy steels can be stopped or materially reduced by "Alumicoat." Adequate high-temperature protection can be provided as long as the base metal has useful strength. According to test reports, at temperatures exceeding the melting point of aluminum, the aluminum diffuses into the steel, forming an intermetallic compound of iron and aluminum. This resulting refractory material is said to give the steel maximum protection against high-temperature scaling.

Low-alloy or mild steels, aluminum dipped, are reported being used to replace high-alloy steels in some applications. Among these uses are jet aircraft parts, boiler tubes, and diesel exhaust pipes and mufflers.

North American Aviation Inc. has begun work on a $5 million wind tunnel to test airplane and missile designs for the future at speeds up to more than three times the speed of sound. Expected to be one of the nation's largest, privately owned wind tunnels, the North American facility will help in solving increasingly complex design problems for airplanes and missiles. The tunnel will be large enough to test models up to 4 feet wide.

Martin Aircraft Co. has established a separate Nuclear Division it was announced recently. Tibor F. Nagey, manager of the new di-

vision, said efforts will be directed toward making Martin a major supplier of portable nuclear power equipment for the military services. Martin plans to develop nuclear reactors and related components for military, industrial, and commercial use.

Robert E. Gross, president and board chairman of Lockheed Aircraft Corp., Burbank, Calif., has been elected president of the Institute of the Aeronautical Sciences for 1955, it was announced by the engineering society's headquarters in New York. He succeeds J. L. Atwood, president of North American Aviation Inc.

Designers Hold Key To Longer Vacations

Designers had better keep on turning out those new and better machines if they want U. S. industry to live up to the latest 10-year prediction. A recent U. S. Department of Commerce forecast says that by 1965, output per man hour will increase 40 per cent while hours of work will be slightly less. Improved production methods and equipment will account for the change.

A summary of the report predicts the following:

- Population will increase 20 per cent to 190 million.
- Output per man hour will increase 40 per cent.
- Hours of work will be slightly less.
- Total national output will increase 50 per cent.

This indicates that salaries will probably be higher with just a little more free time to enjoy that extra income.

American Society for Engineering Education will hold their 63rd Annual Meeting June 20-24, 1955, at the Pennsylvania State University, State College, Pa. Over 200 separate papers, symposia, and round-table discussions will be pre-

(*Continued on Page* 36)

Announcing

A New Heavy-Duty Machine Tool Limit Switch With 70° Overtravel

- Trigger Fast Action
- High Contact Pressure
- Versatile In Application
- Strongly Constructed
- Long Lived

Model L-100S

Acro, a leading manufacturer of precision snap action switches, has now added the sturdy Model L-100S for the machine tool industry. With repeated use of 70° overtravel this rugged design has consistently withstood 20,000,000 actuations. For installation ease, terminals and the switch mechanism are in separate compartments. The heavy cast case is gasketed for oil and moisture resistance. Available with a wide variety of actuators. Easy to service. Electrical rating 25 Amps, 125 Volts AC-DC. Favorably priced. Write for bulletin.

ACRO MANUFACTURING COMPANY

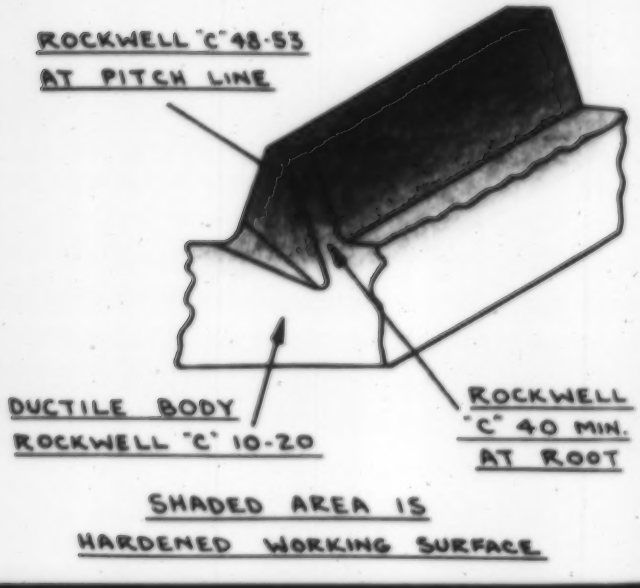
ACRO SWITCH DIVISION

COLUMBUS 16, OHIO

Plants at Columbus and Hillsboro, Ohio

REPRESENTATIVES IN ALL PRINCIPAL CITIES

THIN! TOUGH! ...and "tender-hearted"



THE MANUFACTURE of flywheel ring gears poses special problems. Sectional thickness is usually less than three-quarters of an inch. To withstand the impact force of the starter pinion, the gear teeth must be hard. But the gear body itself should be unhardened so that it will conform tightly to the flywheel, and "give" under the stress that might snap a brittle gear.

Note how DOUBLE DIAMONDS are made to be thin, tough, "tender-hearted." The above photo of a gear twisted into a pretzel shape graphically demonstrates ductility. The sketch at right shows three important areas: the wide and deep hardness pattern, the generous area of transition, and the ductile body. These extremes are achieved in DOUBLE DIAMOND Flywheel Ring Gears by controlled selective heat treatment—all essential to flywheel ring gears that provide the best possible performance.

Our Engineering Department will be glad to make constructive suggestions on the design of flywheel ring gears, or on the many other types in which we specialize. Write, phone or wire—depending on the urgency of your need.

DOUBLE DIAMOND GEARS

FOR AUTOMOTIVE, FARM EQUIPMENT AND GENERAL INDUSTRIAL APPLICATIONS
GEAR-MAKERS TO LEADING MANUFACTURERS

Automotive Gear Works, inc.

ESTABLISHED IN 1914

RICHMOND, INDIANA

A Century MOTOR With Gas Mask PROTECTION

Underwriters Approved EXPLOSION PROOF MOTORS

Take a look at these Century Explosion Proof Motor Features:

- Vital motor parts protected—sealed into inner frame.
- Motor can be reversed without changing direction of the fan—fan runs in either direction.
- Uniform ventilation surrounding outside of inner frame.
- Smooth, straight-through ventilating passages.
- Winding electrically insulated 6 different ways.
- Unusually free from vibration.
- Ball bearing housing keeps grease in—dirt out—lubricated for several years' normal service, with grease plugs for additional lubrication, if necessary.
- Easy-to-remove fan guard is held securely in place with two screws.
- Smooth exterior surface is easy to clean.
- Cast iron frame with integrally cast feet resists rust and corrosion—even when mounted in places where processed materials may contact the feet.
- Rugged construction gives generous safety factor for rough handling.

CE-773

Your property and employees are protected, because this Century Explosion Proof motor is totally enclosed—sealed to prevent a motor spark from causing an explosion.

Class I, groups C and D are used in atmospheres containing flammable gases or vapors: Ethyl ether vapors, gasoline, petroleum, napthha, alcohols, acetone, lacquer solvent vapors and natural gas.

Class II, groups E, F and G are used in atmospheres containing combustible dusts: Metal dust, carbon black, coal or coke dust and grain dusts.

Naturally, corrosive or abrasive materials in the air are also sealed out of the vital parts.

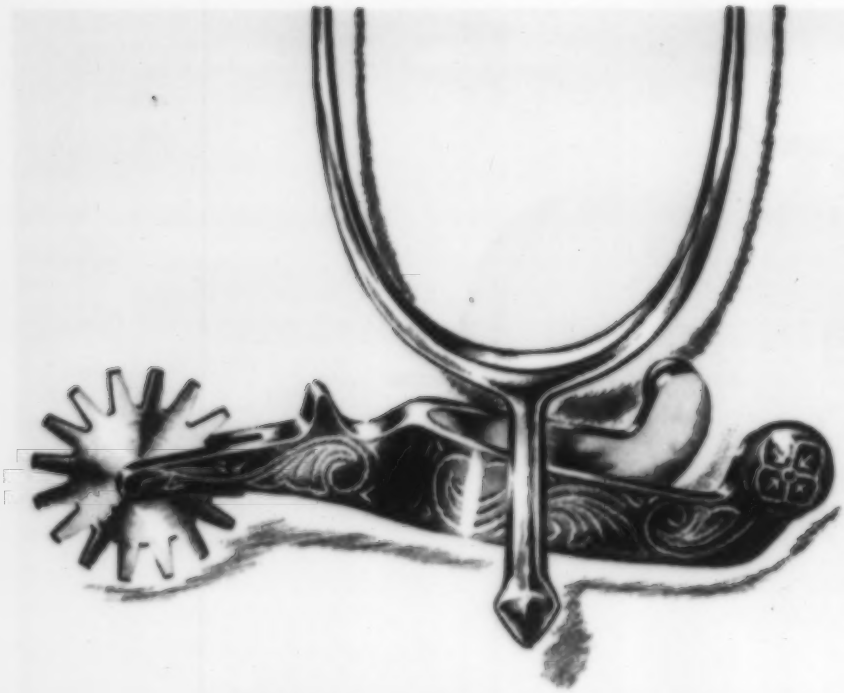
For your protection specify Century motors on the equipment you design. Century Engineers are always ready to work with you . . . to assist you in selecting the motor which will enable you to get top performance from your machine. These engineers can give you complete information on Century's wide range of motors—from 1/8 to 400 horsepower.

Century C MOTORS

CENTURY ELECTRIC COMPANY

1806 Pine Street • St. Louis 3, Missouri

Offices and Stock Points in Principal Cities



Choose one . . .

You can see at once that these spurs differ; serve different need. Suppliers differ. Titeflex was born and raised on a custom-engineering way of doing business. Fresh thinking comes naturally to them. Titeflex people like to tackle the tough ones.

When you buy any Titeflex product you get something extra for your money—Titeflex interest in you. Take time to learn the difference. Send the coupon along today.

Titeflex

☐ Seamed and Seamless Metal Hose

☐ Ignition Harness and Shielding

☐ Precision Bellows

☐ Quick-Seal Coupling

TITEFLEX, INC.
INDUSTRIAL PRODUCTS DIVISION
508 Hendee Street, Springfield, Mass.

Please send me without cost information about the Titeflex products checked above.

Name_____

Title_____

Firm_____

Address_____

City_____ Zone_____ State_____

Left—Western spur with 16-point rowel Right—English spur with straight rowel

News Roundup

(*Continued from Page 31*)

sented at general sessions and in the programs of the 27 divisions of the Society. Information and registration forms may be obtained from Prof. K. L. Holderman, General Chairman, 103 Mechanical Engineering Building, The Pennsylvania State University.

New Computer Shows What You've Got

Actual graphs of the calculated result of a computer's problem appear on the cathode-ray screen of this new computer. Known as the type 740 by its makers, International Business Machines Corp., the unit shows a visual display of the result.

For example, IBM engineers

New visual display computer made by IBM showing the 21-inch cathode ray screen. Here the machine has computed the path of a bouncing ball

claim that successive portions of a computed cam may be displayed on the screen. This display may be photographed at high speed.

Exact course of an aircraft

icked up by radar can be plotted n the screen according to IBM. osition and heading of the plane an be fed to the computer from he radar unit. From these, the omputer quickly calculates the ath of flight and displays it on he cathode-ray screen.

A 21-inch cathode ray tube is sed for the visual display. Photoraphs may be obtained with a 5-mm pulse-operated camera. Accuracy of displays on the 21-inch creen is 3 per cent. A point displayed lasts about 20 seconds. All perations of the displays and camra are automatic and under control f the computer.

• • • COLOR-BLIND DESIGNERS *ill have no excuse for poor coloring of standardized colored products nymore. Armour Research Foundation has acquired a General Electric recording spectrophotometer to be vailable for industrial testing. It tandardizes colors by reducing them to a curve. Costing a neat* $17,000, *the outfit takes the guess work out of what is and what isn't parisian blue, snowshoe white and fantasy yellow.*

Weld Steel to Cast Iron Easier with New Electrode

A newly developed welding electrode with a bimetallic core is the basis of a new technique for welding steel to cast iron. Called a 100-X electrode by its makers, C. E. Phillips & Co., it has a core made of copper and mild steel with an arc-shielding flux coating.

Good bonding of steel and cast iron by welders of average skill is now claimed possible. Repair welding on all grades of iron castings is one of the uses of the new rod. Other possible uses are welding cast iron to carbon and alloy steels, welding heavy cast-iron sections without studding, and welding copper to cast iron. Tensile strength of the bond is said to be higher than cast iron, and the bond is tough, ductile and shock resistant.

Iron castings combined with rolled steel plate are now practi-

...to handle vibration, temperature and corrosion headaches in conveying applications

Do you have to conduct water, solutions, fuel, lubricants, oxygen or other gases or liquids between two points which may not remain fixed? Your answer is Titeflex flexible metal hose.

Titeflex offers you just about everything you could wish for in metal hose—seamed or seamless, braided or unbraided, a wide choice of alloys and fittings. And Titeflex has the originality and experience to simplify your design difficulties—the laboratory control and development engineering assistance you want behind you. All you have to do is send your drawing; we fill in the exact hose type required. ***Telephone or mail in the coupon for full information about metal hose and its uses. catalog 4200.***

Titeflex

FLEXIBLE METAL HOSE

TITEFLEX, INC.
Industrial Products Division
508 Hendee Street
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Your knowledge of metal hose applications may be helpful to us. Please send your complete catalog—without obligation.

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Title_____

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Address_____

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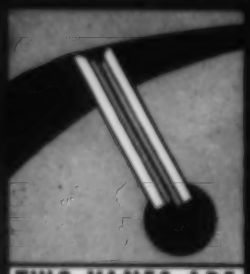
Brute Strength or Delicate Handling of Rotary Power Functions . . .



TWO VANES ARE BETTER THAN ONE

The hydraulically balanced DUAL-VANES in DUDCO Fluid Motors, as contrasted with conventional designs, maintain MULTIPLE AREAS OF CONTACT ON THE CAM RING . . . doubling the number of effective barriers to slippage and power loss. This patented principle is an exclusive DUDCO feature!

DUDCO
FLUID MOTORS

Compact and sturdy, DUDCO DUAL-VANE Fluid Motors operate quietly and smoothly under the most strenuous conditions. They're built to "take it" . . . frequent reversals, rapid accelerations or stalling under load. With DUDCO you get the big advantage of 2000 psi operation at a cost comparable with that of lower pressure equipment.

DUDCO is a big, exciting story for every hydraulics engineer because . . . power losses are minimized and operating efficiency is higher . . . starting torques are high . . . operation is smooth, quiet and exceptionally free from wear or maintenance problems.

On Conveyor systems for agricultural, food processing, mining and other industries, DUDCO DUAL-VANE Fluid Motors provide the extras in performance that save time, money and labor. Operating

the winches on a giant tank retriever and other large mobile equipment calls for high starting torque and the dependable power of DUDCO DUAL-VANE MOTORS.

Write for Bulletin DM-301 fully describing DUDCO DUAL-VANE Fluid Motors today!

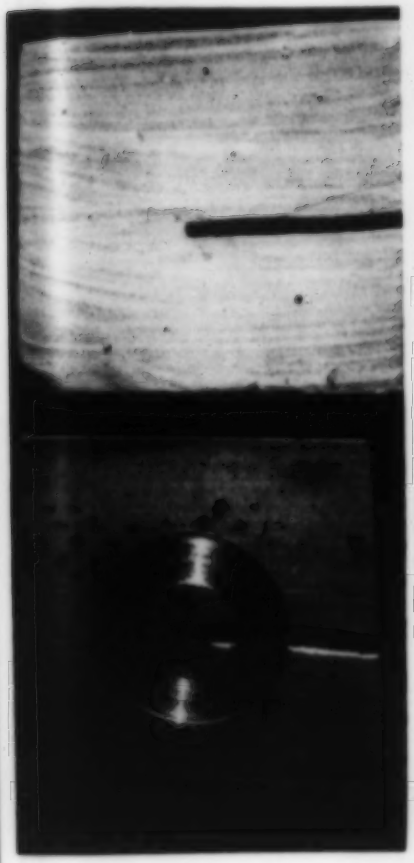
DUDCO DIVISION
THE NEW YORK AIR BRAKE COMPANY
1786 EAST NINE MILE ROAD • HAZEL PARK • MICH.

cal, according to the manufacturer. Another possible advantage of the new technique is to permit engineering changes on castings to be made where previously a new pattern was needed.

GROUND HANDLING of airplanes is done by electric motors in this newly designed docking device. A 20-hp drive motor powers a device that moves the airliner sideways up to an unloading dock in about 40 seconds. The device, made by the Whiting Corp., is said to save airport space, reduce danger of collisions and protect passengers from the weather

Facilities for an expanded program of pilot-plant and large-scale research for American industry are nearing completion at Battelle Institute's recently purchased 400-acre site just outside Columbus, O. The new facilities, according to Clyde Williams, Battelle's president and director, will be used primarily for large-scale studies in chemical engineering, metallurgy, and minerals processing. Provided initially are two major buildings, totaling 13,000 square feet and designed specifically for large-scale experimental work.

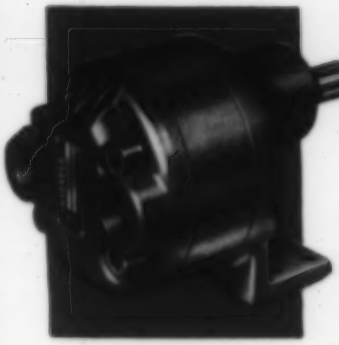
New sheet and foil rolling mill is being constructed by Kaiser Aluminum & Chemical Corp. To be located at Ravenswood, W. Va., the plant is expected to be in operation in 1956.



PAINTED ON TUNGSTEN coating protected the brass square above while the one below was worn down to a depth of 1/16-inch. Both were subjected to the same pretreatment. A new metal-cladding called "Tungstide" announced by the Lockrey Co. may be applied by brush, dip, or spray where a "case-hardening" effect is desired, and is also said to be self lubricating. This tungsten hard coating is being tested in such applications as reducing wear of relay-latching members and plastic drilling and assembly jigs

Hamilton Watch Co. has announced the acquisition of the Hathaway Instrument Co. of Denver. Hathaway produces oscillographs, galvanometers, strain analysis equipment, seismographs and pressure and temperature recorders. Claude M. Hathaway, founder

(*Continued on Page* 42)



These famous Gear Type Motors operate with pressures up to 1500 psi. Available in flange or foot-mounted models, in a complete range of sizes to 52 hp. They feature the exclusive HYDRECO Four Bolt design which places greatest strength in the area of greatest pressure.

with

HYDRECO FLUID MOTORS

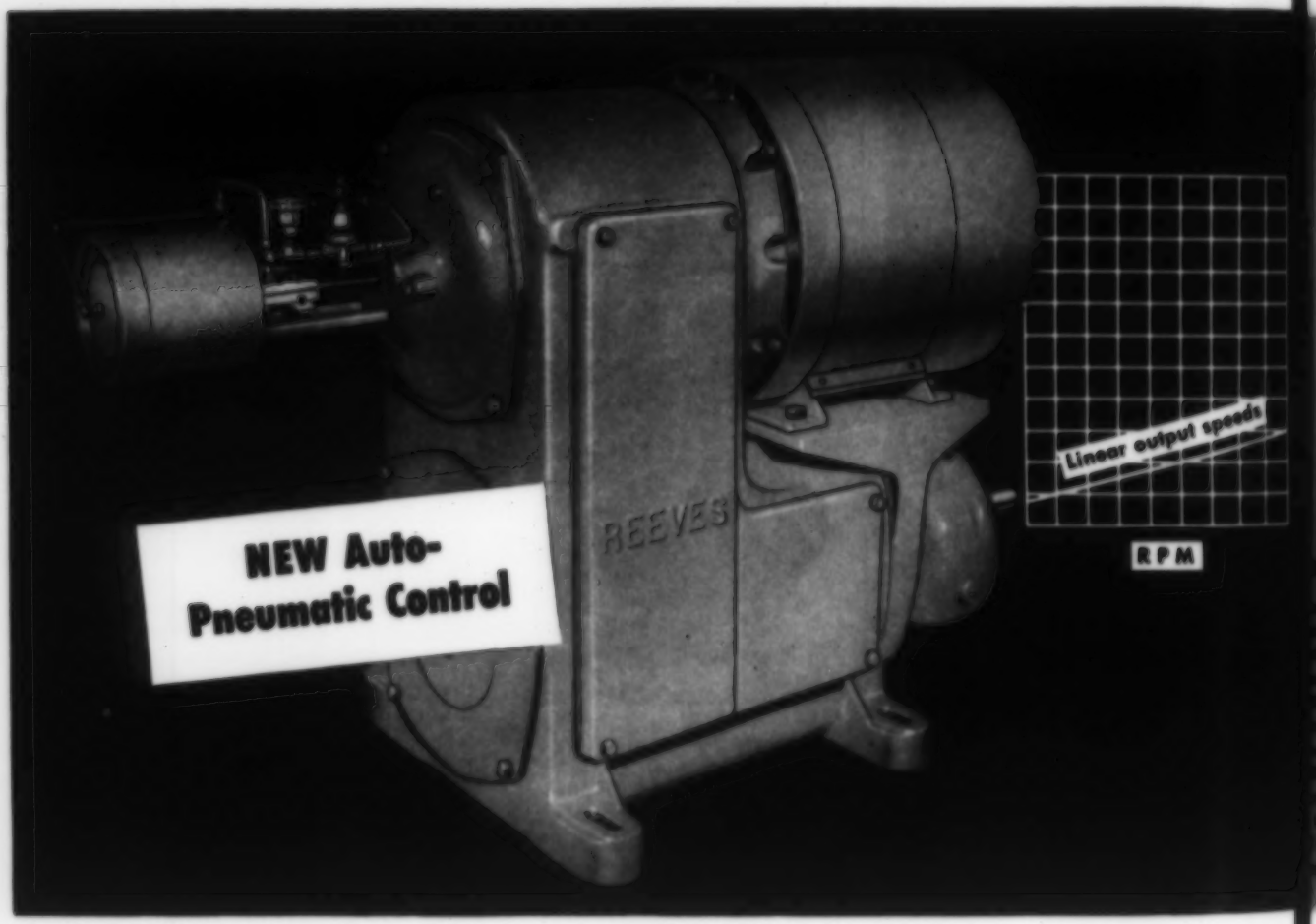
You find the answers to so many problems in the wide experience of HYDRECO engineers . . . especially where a function involves rotary motion. Powering the sweeper or the snow blower on municipal equipment, driving conveyor belts on trenchers, or shaking walnuts out of the trees at harvest time . . . these are but a few of hundreds of money-saving operations HYDRECO Fluid Motors are called upon to perform.

HYDRECO Fluid Motors, with their high starting torque, instant reversibility, and capacity for handling rugged and seemingly impossible assignments, are the natural choice of design engineers. HYDRECO dependability stems from the fundamentally sound "Pressure-Balanced" design, unmatched craftsmanship and the "know-how" of thousands of outstanding hydraulic applications.

Write for full information on HYDRECO Hydraulic Pumps, Motors, Valves and Cylinders today!

HYDRECO DIVISION
THE NEW YORK AIR BRAKE COMPANY
1106 EAST 222nd STREET • CLEVELAND 17 • OHIO

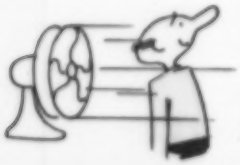
Automatic Process Control ?



for controlling . . .

LIQUID LEVEL

HEAT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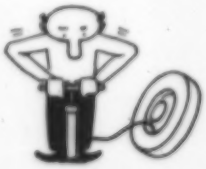
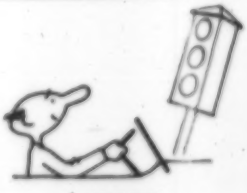

PRESSURE

FLOW


COLOR

. . . AND MANY OTHER PROCESSES

It's as simple as 1-2-3 with

REEVES

AUTO-PNEUMATIC CONTROL

EQUALS AUTOMATIC PROCESS CONTROL

...UMENT CONTROLS

...t instrument controls have been de-...d by many specialists in the instrument ...y . . . instruments that measure changes in ... of various processes, such as heat, ...ical heights, etc. These instrument controls ... the measured change into representa-... air pressure which is passed along to the ... Auto-Pneumatic Control. Control manu-...ers have established a standard range of ... 15 p.s.i. air signal to send out, each fraction ... p.s.i. representing a measured change in the ...

AUTO-PNEUMATIC CONTROL

The control is simply a valve positioner and a pneumatic piston that is connected to the speed shifting mechanism of the Vari-Speed Motodrive. Any change in the position of the piston automatically changes the output speed of the Motodrive. The position of the piston is determined by a "Linear" valve positioner which is operated from the 3 to 15 p.s.i. signal which is sent from the instrument control. Each minute change in instrument air pressure is transmitted to the positioner and actuates a definite increment of RPM change on the Motodrive output speeds.

REEVES VARI-SPEED MOTODRIVE

The Auto-Pneumatic Control may be applied to the fractional and integral HP REEVES Motodrives. REEVES Motodrives are available in both vertical and horizontal design to meet the most exacting space limitations . . . are constructed to stand the most rugged service, yet are highly accurate and sensitive for modern automatic speed control. For further details on REEVES Motodrives, request the complete Motodrive catalog or consult your nearest REEVES representative.

Send today for these two REEVES Bulletins on Automatic Process Control

AUTOMATIC PRODUCTION CONTROL H14a-G537

AUTO-PNEUMATIC CONTROL H14a-M542

REEVES SPEED CONTROL

REEVES PULLEY COMPANY • COLUMBUS, INDIANA

another filter problem solved . . .

R-F NOISE REMOVED FROM ELECTRIC DRILL

Photo courtesy The Black & Decker Mfg. Co.

PROBLEM—R-F interference caused by portable electric hand tools was once quite a problem for the military. To suppress the noise from such small equipment, engineers tried outboard filters and shielded line cords. But these proved to be expensive, bulky, and generally inconvenient. In addition, leakage current from line to tool frame was increased—in some cases to a hazardous extent.

APPROACH—The Black & Decker Manufacturing Co., maker of the drill illustrated above, submitted the problem to the Radio Noise Suppression Laboratories of the Sprague Electric Company in Los Angeles.

SOLUTION—Sprague designed a tailor-made filter which meets all the requirements of size, weight, and performance. Eliminating all radio noise, the filter is still small enough to be installed in the drill housing.

FILTER PRODUCTION SCHEDULES for this drill and small electric hand tools made by other manufacturers are regularly met by Sprague plants on both coasts. Perhaps we can solve your problem too. Write, wire, or phone Sprague Electric Co., 11325 W. Washington Blvd., Los Angeles 66, Calif. (TExas 0-7491) or North Adams, Mass. (MOhawk 3-5311).

Sprague on request will provide you with complete application engineering service for optimum results in the use of radio noise filters.

YOU CAN DEPEND ON

SPRAGUE

WORLD'S LARGEST CAPACITOR MANUFACTURER

News Roundup

(*Continued from Page 39*)

of the company, will remain as president, and John A. Connon of Hamilton will become general manager.

Chicago Belting Co. has announced a consolidation with its two subsidiaries, the Allis Rubber Corp. and the Allis Seal Corp. The new corporation is to be known as the Chicago-Allis Mfg. Corp.

Predictions Indicate What 1955 Graduates Can Expect

Results of a recent survey made by the 1955 Midwest College Placement Assoc., and reported by the Engineering Manpower Commission, tell college seniors how they may stand with regard to jobs and salaries upon graduation this year. Several companies were asked whether they would hire more, less, or the same number of college men in technical jobs this year as compared to 1954. Their answers were:

More than 1954	32
Same	102
Less than 1954	26

About as many think they will need fewer graduates as those expecting to need more. Generally, it seems rate of hiring will remain about the same. According to the report, the same condition existed in 1954.

In addition, the survey questioned companies on the salaries they expect to offer. The accompanying table lists salaries that may be offered technical men without previous industrial or business experience.

Estimated Monthly Salaries for 1955 Graduates

Salary Range	B.S.	M.S.	Ph.D.
$250 or under	1	..	..
251–300	8	..	..
301–350	58	14	3
351–400	93	53	3
401–450	1	48	10
451–500	..	..	8
501–550	..	..	22
551–600	..	..	16

Figures are number of companies reporting.

Apparently graduates with a Master's degree will fare only slightly better than Bachelor's graduates. Ph.D's may expect to do considerably better salary wise to start.

Salaries for nontechnical jobs, also listed in the results of the survey, indicate they will run about $50 a month less in each category.

"It's certainly an interesting linkage, but I'd like to point out that you could replace it with a pulley."

Stuck-Up Airplanes Possible with New Adhesives

Flying high in a metal airplane held together with "glue" may sound a little bit shaky, but new adhesives and new fabrication methods may soon make that a reality. Recently developed metal-to-metal adhesives may make possible new methods of assembling aircraft structural parts. Substitution of adhesives for rivets in fabrication of some aircraft components is expected to result in structural, weight-saving and economic advantages.

Discussed in a recent National Bureau of Standards report, metal-to-metal adhesives were evaluated as bonding for sandwich panel and sheet-stringer panel construction. Sandwich panel construction is used in the fabrication of skins and floors for pressurized aircraft fuselages. These components are subject to lateral pressures and axial loads simultaneously.

The outer two layers of a sandwich panel determine the elastic and strength properties of the panel. The core, of a light material, keeps these facings from becoming elastically unstable. One

tomorrow's transmission TODAY!

PLAN-GEAR PGT TRANSMISSION

AS SIMPLE TO OPERATE AS AN ELECTRIC MOTOR

Anyone can easily operate the new **PGT compound planetary transmission** by merely moving a single hydraulic control lever. With two forward and one reverse speeds, instantaneous selection is possible because the cushion shift action of the **PGT** prevents shock loading. Shift is made from full speed forward to full speed reverse in only 1½ seconds.

CONTROLLED BY HYDRAULIC PRESSURE

The **Plan-Gear Transmission** has two planetary gear assemblies for low and reverse and a multiple disk clutch for locking planetaries in direct drive. The planetaries are actuated when hydraulic pressure contracts a band around an anulus or drum to provide the desired movement. A built-in oil pump provides pressure for actuating controls, lubrication, and flow to the torque converter.

The simply designed, sturdily built **Plan-Gear Transmission** has been tested exhaustively and successfully in the field as well as in the laboratory, and has proved superior to other more complex transmissions. If you have need for a transmission with 150 pound-feet continuous input torque, we'd like to discuss the matter with you. Write today for further information.

PGT-150 PLAN-GEAR compound planetary transmission

is rated at 150 pound-feet continuous input torque; self-lubricated, constant duty, for use with torque converter. Standard ratios: high, 1:1; low, 3:1; reverse, 3.2:1; optional reverse, 2.23:1.

Suggested Uses:

- Front end loaders
- Lift trucks
- Earth movers
- Hoists and cranes
- Car pullers
- Slushers
- Machine tools
- Conveyors
- Power take-offs
- Truck mixers
- Road rollers

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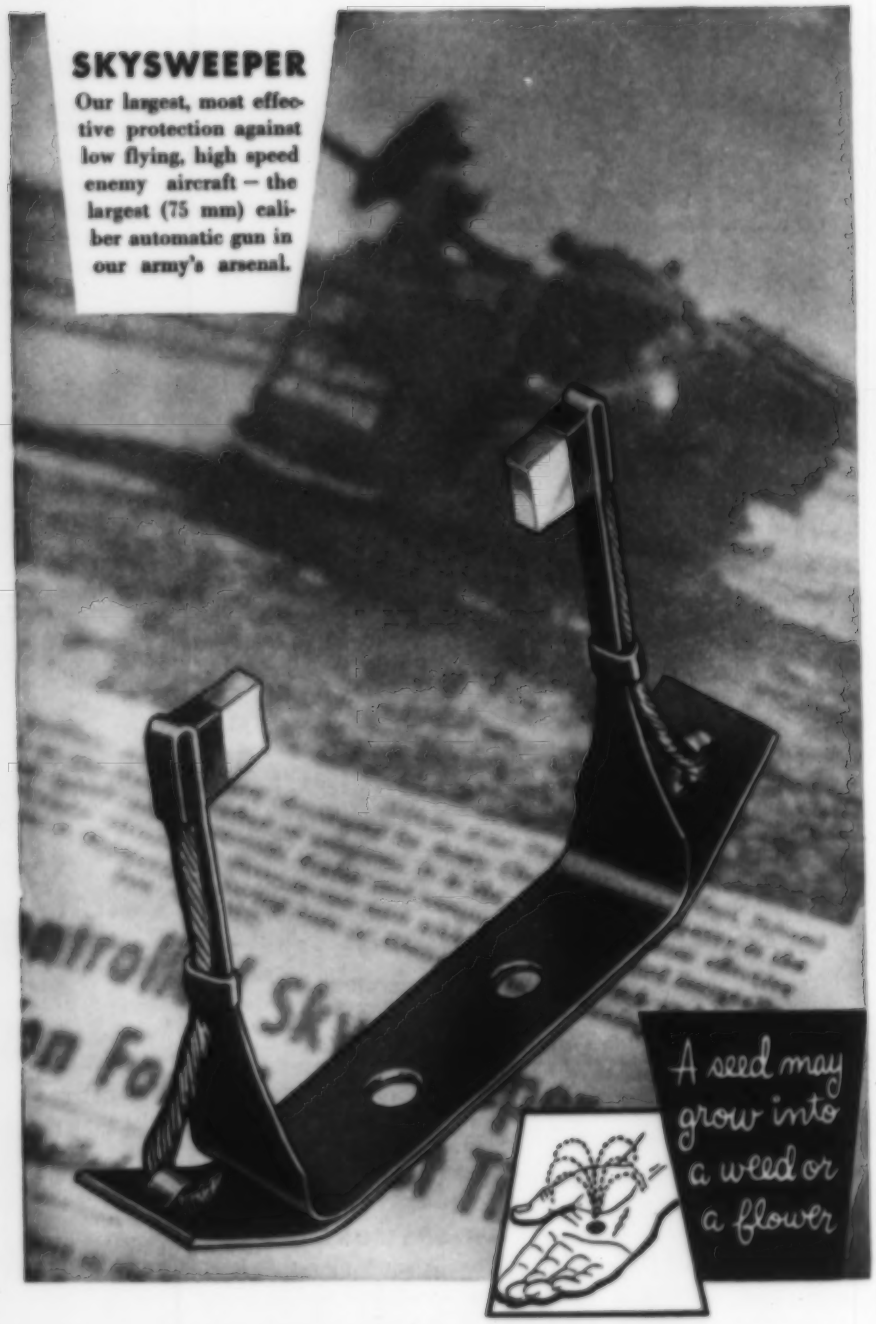
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Our largest, most effective protection against low flying, high speed enemy aircraft — the largest (75 mm) caliber automatic gun in our army's arsenal.
A seed may grow into a weed or a flower

—and a CARBON BRUSH can operate or wreck a great Skysweeper....

A tiny brush in the huge program of national defense—but how powerful for safety or ruin! Contacts and brushes developed, like this one, by the Superior technical staff hint at our readiness to ferret out *your* exact requirements —to work long and closely with you as your needs demand.

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SUPERIOR CARBON BRUSHES
"Since 1919"

News Roundup

advantage of sandwich construction is its relatively light weight. Its high bending stress and stiffness are due to its high ratio of cross-sectional moment of inertia to weight. Absence of rivet heads is another desirable advantage from an aerodynamic standpoint.

Test results of sandwich construction were compared with theoretical values based on column theory. Good agreement was reported obtained between theory and tests for flexural rigidity and failure under various loading conditions.

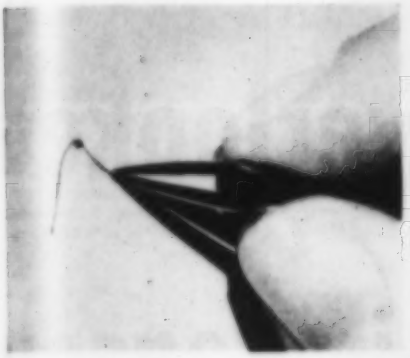
Adhesives have been applied to the more conventional sheet-stringer construction. Most of the outer skin of an aircraft consists of a sheet with stiffeners attached longitudinally to one side. The sheet provides the aerodynamic contour while the stringers provide the necessary strength. Generally, the stringers are riveted to the sheets.

An advantage of bonded sheet-stringer panels is the broad area of attachment between the stringers and the sheet, which reduces the unsupported sheet width. As a result, the load necessary to produce buckling may be increased. Inter-rivet buckling and stress concentrations near the rivet heads which tend to produce buckling between stringers are eliminated.

Results of tests of bonded sheet-stringer panels were reported to compare favorably with riveted panels except the mode of failure in flat-end compression. Here, bonded panels were almost completely destroyed when maximum load was exceeded. Failure of riveted panels was confined to local buckling of the sheet and stringers between rivets.

Difficulty of inspecting bonded joints seems to be one of the most important factors standing in the way of universal acceptance of adhesive bonding in aircraft structures. According to NBS researchers, small changes in humidity, pressure and temperature may produce imperfections that can decrease the strength of the joint. Imperfections such as these can be detected only by destructive tests. Before metal-to-metal adhesive bonding can be universally applied

to all types of aircraft structures, says NBS, either completely reliable fabrication procedures or satisfactory inspection procedures must be developed.



ONE-TENTH OF A PIN-HEAD is the size of this smallest commercially available thermistor. According to Thermister Corp. of America, the units can be heated more than 10 C above ambient temperature by only 1 milliwatt of electrical power. They are used as sensing units in applications such as liquid level detection

New Material Cools Jet Parts

Development of a new porous metal intended for use in cooling high temperature equipment was announced recently. Called "Rigimesh," the new porous medium is being manufactured by Aircraft Porous Media Inc.

In manufacture, warp and woof strands of one or more layers of woven wire cloth are welded together. A homogeneous plate is mechanically formed, with finer openings than the woven wire cloth.

Any alloys that can be drawn into wire are suitable construction materials, the company reports. Stainless steel types 304 and 316 are available for moderate temperature service. Alloys such as L-605 will be available for higher

(*Continued on Page* 48)

DON'T CUT PARTS ...Cut Costs!

Why pour money into expensive machining operations?

POWDERED METAL PARTS can do the job for *much less!*

Tough, intricate parts ready for assembly without further processing—at *savings of up to 600% over identical machined parts!* No wonder industry chooses Powdermet.*

Low-cost PM parts are die-pressed to close tolerances, have excellent wearability, and a wide range of alloys are available—many exceeding the tensile strengths of mild steel. Through controlled porosity and electrical permeability, many special properties are achieved . . . such as oil-impregnation for life-time self-lubrication. That's why Powdermet* parts are often the *best parts possible* for gears, bearings, filters, etc.

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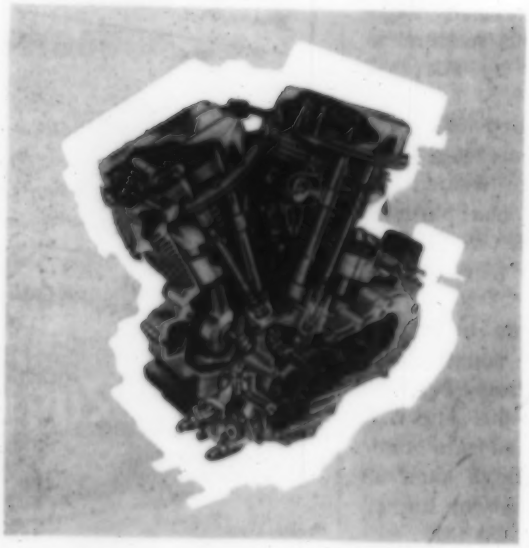
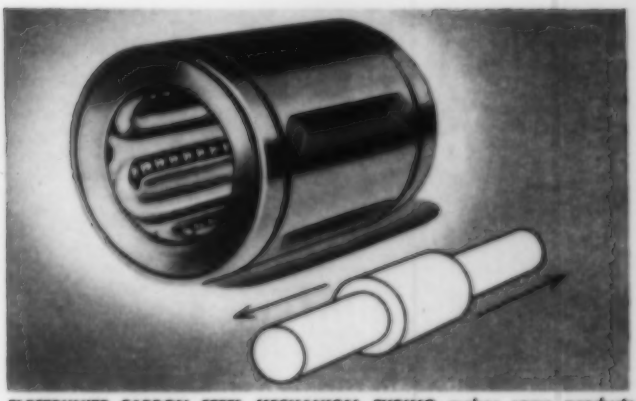
Have you overlooked the big reason for using alloy steels?



When horsepower was increased on the Harley-Davidson motorcycle from 30 to 55, company engineers were faced with designing a transmission that could take the tremendous impact and stress. Republic metallurgists suggested Republic's 8617 Alloy Steel. The result was: reduction of section; good heat treating and carburizing properties; more horsepower from the same size transmission.

PAINT REALLY ADHERES to Republic Electro Paintlok sheets. And rust is shut out. That's why these National Biscuit Company truck bodies are made of this zinc-plated steel sheet that's chemically treated to take paints, lacquers, synthetic enamels — and hold them for years. Tight zinc coating guards against underfilm corrosion and creeping rust. Manufacturers of everything from truck bodies to caskets have found production costs go down when they use these special sheets that hold paint longer and make products look better.



ELECTRUNITE CARBON STEEL MECHANICAL TUBING makes some products possible (like this ball bushing for linear motion by Thomson Industries). Problem here was close-tolerance tubing to house bearings and raceway, plus tough wear by bearings at contact points. Republic ELECTRUNITE Tubing supplied all these advantages along with good surface conditions; good dimensional control, both I.D. and O.D.; uniform wall thickness; uniform concentricity; uniformity to withstand heat treating.

A lot of people are under the impression that alloy steels are used only to get certain necessary properties. Heat-treating qualities, for example. Extra fatigue strength. High impact value. High shear resistance. Or many other reasons.

But analysis will show that alloy steels also save money.

There is no better reason for using them. In fact, we don't recommend them unless they do save money, somewhere along the line.

It's just a matter of how much money you want to save. And you save the maximum when you design parts and process properly for alloy steels. That's where we come into the picture. Our 3-D metallurgical service will help you get the properties you want in your products if your engineers and our metallurgists put their heads together.

Let's talk things over now before the competition steps out ahead. A call to your nearest Republic district sales office will get things under way. Have your secretary do it, soon.

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World's Widest Range of Standard Steels and Steel Products

FREEDOM FROM RUST and corrosion makes any product made of Enduro Stainless Steel a good buy. Good example is laundry equipment. Made of stainless steel, it resists rust, corrosion and the action of most washing compounds and detergents. It's easy to keep clean and attractive. And because of resistance to wear, equipment cost can be written off quickly. Republic, pioneer in stainless steel, shows manufacturers how to use it profitably.

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SPEED REDUCERS
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5-1 to 100-1

. . . These and other units are available in single and double reduction, ranging in ratios from 1-1 to 4,000-1. Capacities from 1/6 to 15 HP. See your nearest distributor or write direct.

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OHIO GEARS

THE OHIO GEAR COMPANY
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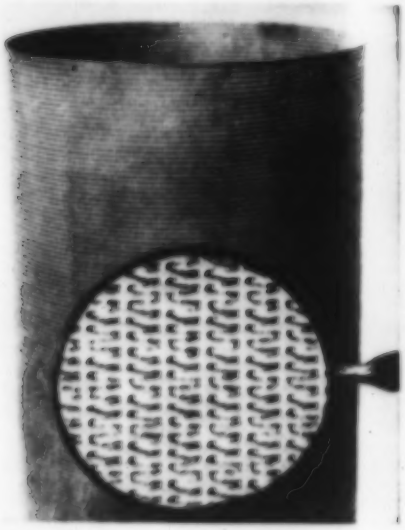
News Roundup

(*Continued from Page 45*)

temperature applications. Heat transfer obtained in the new metal woven from 0.002 to 0.004-inch diameter wire is comparable to



A section of "Rigimesh," a newly developed porous type plate, showing the texture of the surface

that of porous powder-metal materials.

Rigimesh is said to be readily machined, welded or riveted in the same manner as solid metal. It can be made available with directional tensile strength properties for applications requiring high circumferential strength but only moderate axial strength.

First Flight Soon for All Magnesium Airplane

An experimental all-magnesium airplane, an F-80 C, is expected to be flown for the first time within the next few weeks. Built by East Coast Aeronautics Inc., the plane is the second with an airframe made almost 100 per cent of magnesium. The first was fabricated at the Wright Air Development Center and has been successfully static tested.

Tests of magnesium components have been conducted over a number of years by the Air Research and Development Command to determine the suitability of the metal for aircraft structures as a pos-

sible alternative for aluminum. Further, its supply is as nearly inexhaustible as any metal known. In applications where buckling is the controlling design consideration, magnesium is said to be the most efficient structural material throughout the usable temperature ranges of the light alloys. A thicker skin structure, made possible with magnesium, is expected to decrease ground handling damage.

Electrolytic manganese is being produced at the new Marietta, Ohio, plant of Electro Metallurgical Co. Expected capacity is 6000 tons a year when in full production. Plates about ⅛-inch thick of 99.9 per cent pure manganese are being made.

Meetings

AND EXPOSITIONS

Feb. 14-18—

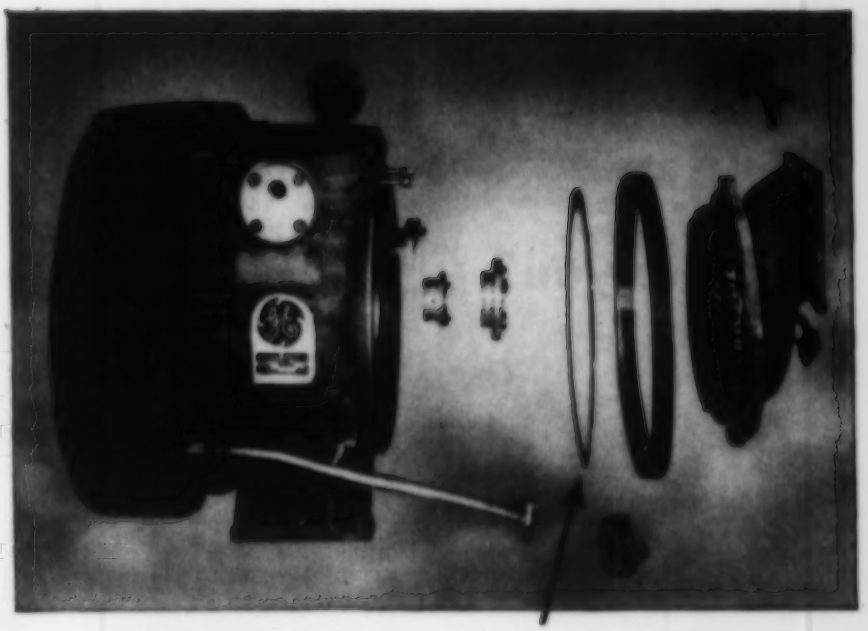
American Institute of Mining & Metallurgical Engineers. Annual meeting to be held at the Conrad Hilton Hotel, Chicago, Ill. Additional information may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.

Feb. 18-19—

National Society of Professional Engineers. Annual spring meeting to be held at Hotel Charlotte, Charlotte, N. C. Additional information may be obtained from society headquarters, 1121 15th St., N. W., Washington 5, D. C.

Mar. 1-3—

Joint Western Computer Conference and Exhibit to be held at the Statler Hotel, Los Angeles, Calif. Sponsered by IRE, AIEE, and Association for Computing Machinery. William Gunning, International Telemetering Corp., 2000 Stoner Ave., Los Angeles 25, Calif., is conference secretary



LAMINUM® adjustable SHIMS

cut assembly costs on turbo-supercharger for diesel engines

THIS is only one from thousands of laminated shim applications throughout all industry. Yet the reason for using laminated shims and the gains resulting are typical. This shim sets the clearance between the nozzle and buckets on the General Electric RD3C turbo-supercharger. Shimming is essential because of the accumulation of tolerances. The laminated shim can be adjusted quickly merely by peeling—and after peeling is always precisely uniform in thickness from end to end and side to side. Peeling is far easier and faster than precision grinding which would prove quite costly on these extremely large shims.

Whenever you need shims, call the Laminated Shim Company *first*...for fast, complete service. We manufacture shims in aluminum, brass, steel—small as a fingernail and large enough for locomotives...laminated, spot-soldered or looseleaf. Produced to your own precise blueprint specifications.

For further information and free booklet telling all about laminated shims and how they're used, please write. No cost or obligation, of course. Write today!

SHIM HEADQUARTERS SINCE 1913

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The name Laminum is registered with U. S. Patent Office

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SHIMS: Custom, standard tapered roller bearing.

STAMPINGS: pilot runs.

SHIM STOCK

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To some, it means Sand Blasting . . . the big blow that gives old buildings that new look. But, to hundreds of industrial designers, it means Small Balls . . . at which Universal is best.

Sure, we make balls from the size of a mustard seed up to that of a walnut, each of them precisioneered for true roundness and silken silence. Write for details.

Universal Ball co.

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MONTGOMERY CO., PA.

Engineering News Roundup

Mar. 7-11—

National Association of Corrosion Engineers. Eleventh annual conference and exhibition to be held at the Palmer House, Chicago, Ill. A. B. Campbell, 1061 M & M Bldg., Houston 2, Texas, is executive secretary.

Mar. 10-11—

Porcelain Enamel Institute. Pacific Coast conference to be held at the Biltmore Hotel, Los Angeles, Calif. Additional information may be obtained from society headquarters, Dupont Circle Bldg., 1346 Connecticut Ave., N. W., Washington, D. C.

Mar. 14-15—

Steel Founders' Society. Annual meeting to be held at the Drake Hotel, Chicago, Ill. Additional information may be obtained from society headquarters, 920 Midland Bldg., Cleveland, O.

Mar. 14-18—

American Society of Tool Engineers. Western Industrial exposition to be held at the Ambassador Hotel and Shrine Auditorium, Los Angeles, Calif. Harry E. Conrad, 10700 Puritan Ave., Detroit, Mich., is executive secretary.

Mar. 16-18—

Pressed Metal Institute. Annual meeting and exhibit to be held at the Carter Hotel, Cleveland, O. Orrin B. Werntz, 2860 East 130th St., Cleveland, O., is managing director.

Mar. 28-29—

American Institute of Electrical Engineers. Materials handling conference to be held at Hotel Cleveland, Cleveland, O. Additional information may be obtained from society headquarters, 33 West 39th St., New York 18, N. Y.

Mar. 28-Apr. 1—

American Society for Metals. Western metal exposition and congress to be held at the Pan Pacific Auditorium, Los Angeles, Calif. Additional information may be obtained from society headquarters, 7301 Euclid Ave., Cleveland, O.

Apr. 13-15—

American Society of Lubrication Engineers. Tenth annual meeting and exhibit to be held at the Sherman Hotel, Chicago, Ill. W. P. Youngclaus Jr., 84 East Randolph St., Chicago 1, Ill., is secretary.

Apr. 16-17—

Packaging Machinery Manufacturers Institute. Spring meeting to be held at the Palmer House, Chicago, Ill. Additional information may be obtained from society headquarters, 342 Madison Ave., New York 17, N. Y.

Apr. 18-21—

American Management Association. Packaging conference to be held at the Palmer House, Chicago, Ill. Additional information may be obtained from society headquarters, 330 West 42nd St., New York 36, N. Y.

Apr. 18-21—

American Society of Mechanical Engineers. Spring meeting to be held at the Lord Baltimore Hotel, Baltimore, Md. C. E. Davies, 29 West 39th St., New York 18, N. Y., is secretary.

Apr. 25-27—

Association of Iron & Steel Engineers. Spring conference to be held at the Statler Hotel, Detroit, Mich. T. J. Ess, 1010 Empire Bldg., Pittsburgh 22, Pa., is managing director.

Apr. 27-29—

Society for Experimental Stress Analysis. Spring meeting to be held at Hotel Statler, Los Angeles, Calif. W. M. Murray, P. O. Box 168, Central Square Station, Cambridge 39, Mass., is secretary-treasurer.

Apr. 28-29—

American Zinc Institute Inc. Annual meeting to be held at the Drake Hotel, Chicago, Ill. Additional information may be obtained from society headquarters, 60 East 42nd St., New York 17, N. Y.

MEN OF MACHINES

Recent appointments at C. A. Norgren Co., Englewood, Colo., include that of **Leigh H. Norgren** as vice president in charge of engineering and production. He has been associated with the company for eight years. **J. A. Wilson,** who has been a design engineer, supervisor of design and drafting, and assistant chief engineer since joining Norgren four years ago, has been named chief engineer. He succeeds **Delbert G. Faust,** who was appointed to the newly created position of vice president in charge of sales and advertising.

Hjalmar Nilsson has been appointed chief engineer of Magnesium Co. of America, East Chicago, Ind. He has been plant engineer since 1947 and before that time was chief engineer of Beatty Machine and Mfg. Co., Hammond, Ind.

General Radio Co., Cambridge, Mass., has appointed **Dr. Donald B. Sinclair** vice president of engineering. Dr. Sinclair joined the company in 1936 and has served as engineer, assistant chief engineer and, since 1949, as chief engineer. A Fellow of the Institute of Radio Engineers, he was president of that society in 1952. He is also a Fellow of the American Institute of Electrical Engineers and a member of the American Association for the Advancement of Science.

Ansel H. Graham has been named manager of engineering of the Small Integral Motor Dept. of General Electric Co. at Fort Wayne, Ind. Mr. Graham joined the company on the test engineers' program in 1939, was named manager of engineering for dc armored motors in 1948, and three years later was appointed assistant to the manager of engineering in the company's former Small and Medium Motor Dept. In 1953 he was named manager of advance and development engineering in the Medium Induction Motor Dept. in Schenectady, N. Y., the position he held until his present appointment.

Chain Belt Co., Milwaukee, has promoted **Bernard Schneider** to chief engineer for the conveyor equipment section. Mr. Schneider has spent almost 30 years in conveyor engineering work.

Michigan Tool Co., Detroit, has appointed **Clayton E. Scott** chief engineer. Concurrently, **Charles R. Staub,** chief engineer since 1936, was named staff consultant. Mr. Scott, who was educated at Lawrence Institute of Technology, joined the firm in 1935. He was named assistant chief engineer in

Clayton E. Scott

*Standard, semi-standard and "special" air and hydraulic cylinders all assembled from large, complete shelf stocks of component parts, then tested and shipped directly from Ortman-Miller's modern new assembly plant . . . assures the *right* cylinder for the job, *delivered in LESS TIME!*

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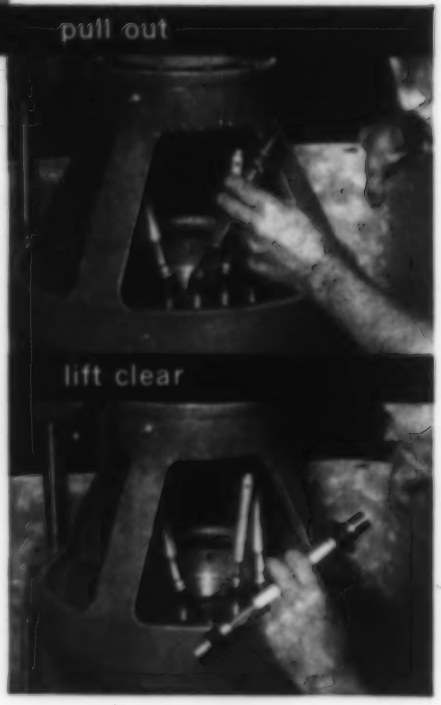
an APEX universal joint assembly helped solve this design problem



may we try to help you with your design problem?

These Apex universal joint assemblies have axially-free, spring-loaded connectors that make it possible to remove or re-position each unit in a matter of seconds. This practical, economical drive for machine designers helped solve the problem of excessive down-time when changing drilling patterns.

If you have a design problem that might be solved with universal joints or universal joint assemblies, we'd like to offer our assistance. The first step is to write, on your company letterhead please, for Catalog 27. In it you'll find complete information on all Apex aircraft and industrial universal joints, plus some very helpful application data sheets.

APEX universal joints

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1036 So. Patterson Blvd. • Dayton 2, Ohio

Men of Machines

Charles R. Staub

1953. Mr. Staub, having joined the company in 1929, has pioneered in the development of modern gear production methods and machines. He is a member of the Society of Automotive Engineers and the American Society of Tool Engineers.

Edward G. Wicklatz has been appointed manager of Alemite and instrument engineering by Stewart-Warner Corp., Chicago. He joined the company's engineering department in 1936 as a draftsman. Most recently he served as chief engineer of Alemite products.

Having joined the Cook Research Laboratories Div. of Cook Electric Co., Chicago, as mechanical development engineer in 1948, **Benedict J. Pardini** was recently appointed supervisor of the drafting and design group.

A. Robert Teasdale Jr. has been appointed to the newly created position of chief of electronics design in the engineering department of Temco Aircraft Corp., Dallas, Tex. He will supervise design and installation of electronics systems. After receiving a B.S. degree in electrical engineering from the University of Texas, Mr. Teasdale joined General Electric Co., Schenectady, N. Y., as a test engineer.

Subsequently he taught at the University of Texas, where he also did research work, and in 1950 he received his M.S. degree from that university. Immediately prior to joining Temco he was associated with Convair's Fort Worth Div.

Lewis F. Herron, president of the James H. Herron Co., Cleveland, has been elected president of the American Council of Independent Laboratories Inc. for 1955.

Dr. Howard Baller has been named manager of electronics research for the Engineering Research and Development department of General Mills Inc., Minneapolis. Since 1949 Dr. Baller has been assistant manager of the electronics department of W. L. Maxson Corp., New York.

M. R. McLary, who joined the division as chief engineer in 1952, recently was appointed works manager of the Ingersoll Products Div. of Borg-Warner Corp., Chicago.

Dr. William Firestone has been appointed to the newly created position of assistant chief engineer in the research department of the Communications and Electronics Div. of Motorola Inc., Chicago. He will be responsible for specific phases of departmental adminis-

William Firestone

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Pressed-in packaged unit recommended for small shafts on hot or cold water, oil, gasoline or soapy liquids . . . pressures to 75 psi . . . temperatures from —65° F. to +220° F. Available in stainless steel or bronze.

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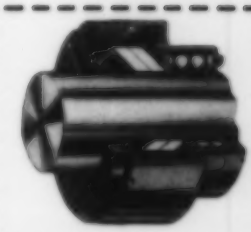
Pressed-in packaged unit with spring inside synthetic rubber bellows to protect against corrosion. For hot or cold water, oil, gasoline or soapy liquids . . . pressures to 35 psi . . . temperatures from —65° F. to +212° F.



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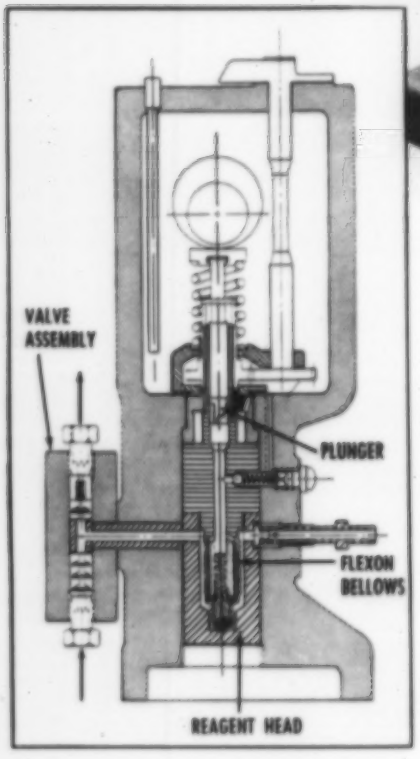
FLEXON BELLOWS *Design Briefs*

Flexon Bellows Pumping Element Operates at 900 strokes/minute in New Packless Metering Pump

At the right is the Hills-McConnameter, described by its manufacturer, Hills-McConna Co., as "the meter that pumps." Through the use of a Flexon Bellows as the pumping element, the Hills-McConnameter provides precise, positive displacement pumping without the use of packing.



The Flexon Bellows pumping element of the Hills-McConnameter is mounted within a reagent head which serves as a pumping chamber. The down stroke of a reciprocating plunger forces hydraulic fluid into the bellows, extending it. This results in a positive displacement of the fluid in the reagent head and causes fluid to be discharged through the valve. On the plunger's upstroke, pressure is relieved and the bellows returns to its free length, drawing more fluid into the reagent head completing the pumping cycle. The pump is designed to operate at speeds up to 900 strokes per minute.

• Flexonics Corporation supplies bellows and bellows assemblies in brass, bronze and stainless steel for vacuum equipment, thermostatic devices, pressure controls, packless valves, pneumatic instruments, hydraulic mechanisms, rotating shaft seals and many other services. For further information and application data, write for your copy of the "Flexon Bellows Design Guide." And when specifying bellows, be sure and specify Flexon Bellows.

Flexonics *Corporation* — FLEXON BELLOWS DIVISION

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Manufacturers of flexible metal hose and conduit, expansion joints, metallic bellows and assemblies of these components.
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Men of Machines

tration and will also continue as head of the advanced investigation section of the research department. Dr. Firestone received his Ph.D. in June 1952 from Northwestern University. He is a member of the Institute of Radio Engineers and the American Institute of Electrical Engineers.

Charles A. Borcher recently joined the Engineering Research Div. of Miller Metal Products Inc., Baltimore. He is in charge of the Ordnance Engineering Dept. and will supervise and manager military research and development work in connection with ordnance projects.

Making his headquarters at a new switchgear plant in Scranton, Pa., **E. A. Williams** has been appointed manager of the eastern switchgear division of Federal Pacific Electric Co., Newark, N. J.

John O. Forster recently joined Ferber Corp., Englewood, N. J., as chief engineer. He was formerly chief engineer of Heli-Coil Corp.

The Guided Missile Div. of the Ramo-Wooldridge Corp., Los Angeles, has announced the appointment of **Dr. Bernard Rasof** as mathematician and aeronautical engineer and **Frank W. Lehan** as electronics research engineer.

Ernest Hartford has retired as deputy secretary of the American Society of Mechanical Engineers after 43 years of service. He will continue to serve the society in a consulting capacity.

C. J. Thompson recently joined the Aeronautical Div. research and development laboratory of Robert-Shaw-Fulton Controls Co., Anaheim, Calif., as chief design engineer.

J. Robert Ferguson Jr. has been named chief engineer of project development by United States Steel Corp., Pittsburgh. He succeeds **Norman C. Michels,** who was ap-

pointed assistant vice president of engineering for the Tennessee Coal & Iron Div.

George W. Kessler has been appointed chief engineer of the Boiler Div. of the Babcock & Wilcox Co., New York. Assistant chief engineer of the division since 1953, Mr. Kessler joined the company in 1930.

Couch-Uthe Co., Elyria, O., has appointed **Stuart W. George** chief engineer. He was formerly chief tool engineer of National Acme Co.

Edward H. Freiburghouse Jr. has been named manager of the new mechanical engineering subsection in the Materials and Processes Laboratory of General Electric Co., Schenectady, N. Y.

Dr. Ernest A. Lederer has been promoted to the newly created position of chief engineer of the electronic tube division of Westinghouse Electric Corp. at Horseheads, N. Y.

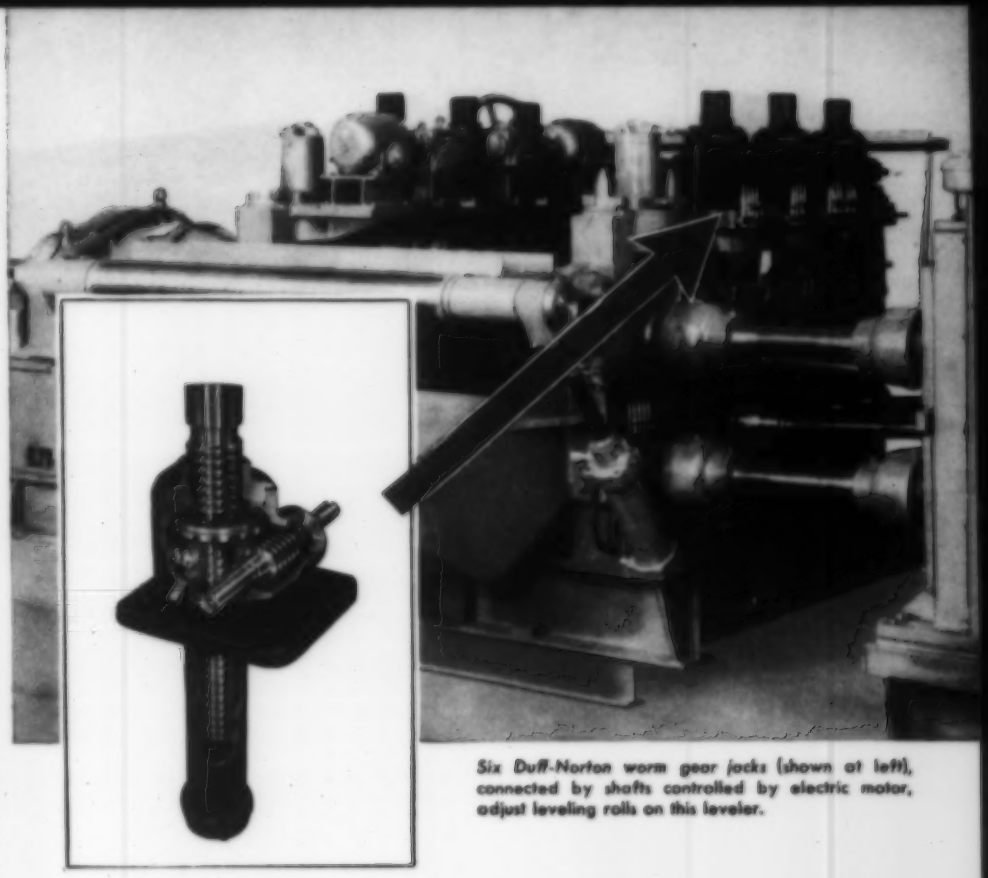
The appointment of **Stanley L. Haines** as director of industrial engineering has been announced by American Locomotive Co., Schenectady, N. Y.

R. T. Zwack has joined Walter Kidde & Co., Belleville, N. J., as chief design engineer. He was formerly staff engineer with the Propeller Div. of Curtiss-Wright Corp.

Richard E. Carpenter has been promoted to chief production engineer of ElectroData Corp., Pasadena, Calif.

International Business Machines Corp., New York, recently named **Carroll F. Lynch** production engineer, **George S. Vermilyea** manufacturing engineer and **Paul F. Heitz** quality control manager.

Robert F. Griffin has been appointed chief engineer of the Herbrand Div. of the Bingham-Herbrand Corp., Fremont, O.



Six Duff-Norton worm gear jacks (shown at left), connected by shafts controlled by electric motor, adjust leveling rolls on this leveler.

Here's a time-tested device for adjusting machinery

It's the Duff-Norton worm gear jack, successfully used by many machine builders as a component of equipment for precise, positive control of linear motion; applying pressure; resisting impact. Two or more of these jacks can be connected by means of shafting and mitre gear boxes or any power-operated positive control system, so that jacks always raise or lower under equal or unequal loads in perfect unison. Capacities range from 5 to 35 tons with any raise up to 25 inches; worm gear ratios, 8:1 to 45:1; turn of worm for each 1 inch raise, 10 to 180; available in either Acme or square threads. Screw ends and tops are available in many types and can be readily adapted to your specific requirements.

Duff-Norton worm gear jacks have been specified by America's leading designers and machinery builders for many years. They are made in 6 standard sizes or to your special order. Write for booklet!

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The Wagner Type RK Capacitor-start induction motor meets these requirements and offers the additional advantages shown at the right. That's why the RK is first choice of many leading manufacturers of machines and equipment that require single-phase motors in fractional or integral ratings up through 5 hp.

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MACHINE DESIGN

FEBRUARY 1955

Sterility at the Grass Roots?

HOW WELL ARE today's engineers measuring up to the concepts of a profession? "Professionalism in any area of endeavor," says W. H. Larkin, "is strictly a grass roots affair. It is basically a way of life, an understanding of the nature of a profession, a realization of its responsibilities, and a willingness to assume a fair share of them."

By at least one criterion—membership in engineering professional societies—the answer is discouraging. Fewer than half of those qualified belong to any such society. And even fewer are registered by their states to practice engineering.

Active membership in a professional society costs a little money and some time and effort. Why do more than half of our so-called profession refuse to pitch in even to that small extent, if only as a gesture and a token of their professional spirit? Because, they say, the societies don't do anything for them. Instead, some of them are joining collective bargaining groups.

But disinterest in professional societies and in registration is only half the story. In Mr. Larkin's view, "Altogether too many individuals in both groups have no conception of what constitutes professional attitude nor what their responsibilities are. The profession is all too sterile at the grass roots, the only level at which vital lasting growth can take place."

A favorite excuse for our shortcomings is "after all, people are only human." Yes, but in defining *professional* the dictionary includes the words "higher motives than mere gain." If he wants to take a lower level of human conduct as his standard, the engineer had better forget about striving toward professional recognition.

Engineering stands at a crossroads. Where our profession goes from here lies in the hands of each and every individual who calls himself an engineer. If we fail to achieve the recognition that engineers' contributions to human welfare so richly deserve, it will be largely because of sterility at the grass roots.

Colin Carmichael

EDITOR

When, where and how to use HIGH-SPEED PHOTOGRAPHY

By William G. Hyzer
Consulting Engineer
William G. Hyzer and Associates
Janesville, Wis.

Many words have been written on high-speed photography, its techniques and successful application to specific engineering problems. From these miscellaneous experiences a philosophy of planned use of high-speed photography at select points in the engineering program is evolving. This article further develops these methods, explains the techniques involved, and offers specific application ideas.

THE bursting whine of the high-speed motion-picture camera is becoming a familiar sound to the engineer in all walks of the profession. No longer a laboratory instrument, these cameras are practical investigative tools for the designer and project engineer.

High-speed photographic techniques in effect "put the brakes on time" so that the eye can analyze in acute detail those ultrarapid mechanical motions that would otherwise be indiscernible. It's like giving sight to a blind man accustomed to feeling and reasoning his way through the dark.

Retardation of time afforded by this photographic method can be as invaluable to the engineer as the microscope to the biologist or the telescope to the astronomer. Certainly, being able to visually record a motion or a microbe or a galaxy and demonstrate it to others for consultation is preferable to a hundred expert opinions based on speculation alone.

This technique, although widely used in practically all fields of engineering endeavor with considerable success, is still in its infancy. Like any new approach, it is being used haphazardly and too often, as a last resort when other methods fail. For maximum effectiveness in the organized product development program, it should be applied as an integral part of that program—not as an afterthought. Its value as an exploratory and investigative technique in engineering work should be recognized by the design or project engineer so that it can be used effectively at the exact points of optimum advantage.

FUNDAMENTALS OF CAMERA OPERATION

Most companies that maintain their own high-speed camera facilities depend upon their plant

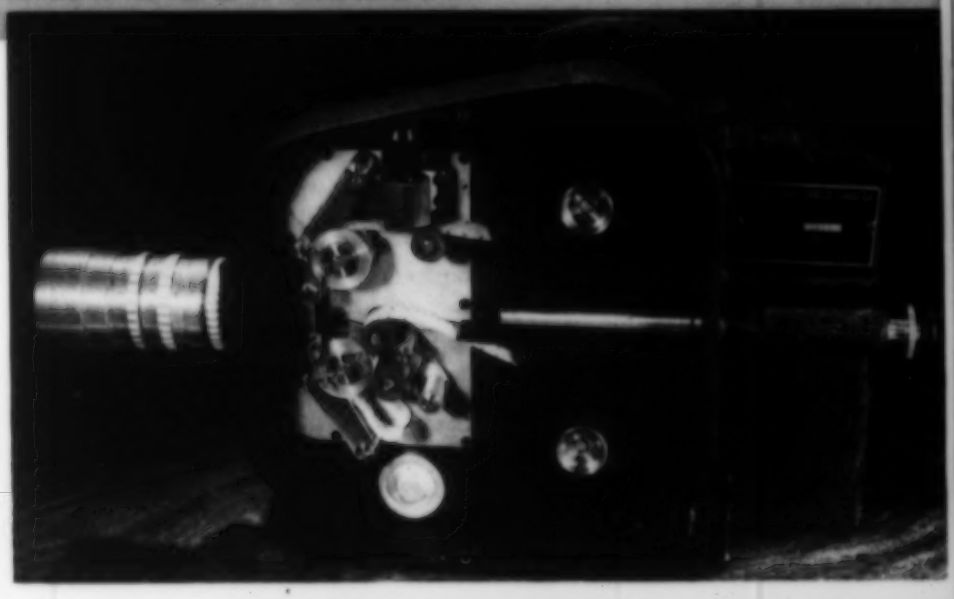


Fig. 1—Kodak High-Speed camera, showing inside arrangement

photographer to master the operation of the equipment and, in many cases, recommend its use. An experienced photographer, if available in the organization, is probably best qualified to operate the equipment. But unless he has exceptional technical ability, he cannot substitute for the project engineer in directing its use. To be efficient in this capacity, the engineer requires only a general familiarity with the fundamental operating characteristics of the equipment and its scope of applicability. This section will briefly discuss these aspects.

Only commercially available high-speed motion picture cameras will be treated in this article. This equipment has proved its versatility for the vast majority of industrial applications. These cameras are portable, utilize standard motion-picture film, and are nearly foolproof in operation.

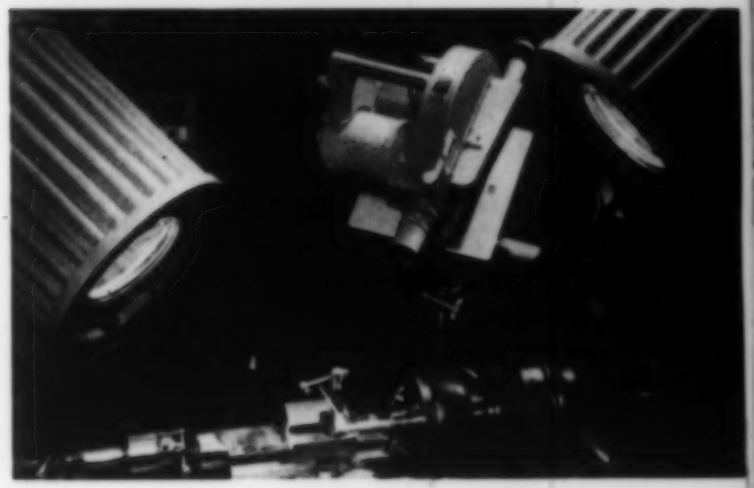


Fig. 2—Fastax 16-mm camera set up for high-speed movies of a metal-turning operation

Time Magnification: In high-speed photographic terminology, the ratio of camera frequency to projector frequency is aptly called "time magnification." A motion slowed down to 1/100 of its actual speed has undergone a time magnification of 100. If the projector frequency is 16 frames per second, the camera frequency required to produce this result would have to be 1600 frames per second.

Obviously, time magnification can be increased for a given film record by slowing down the projector. The limiting projector frequency is about 15 frames per second, at which point the eye begins to detect a flicker in the projected image. The maximum practical time magnification obtainable under any given set of conditions is the camera frequency in frames per second divided by 15.

Frequency or repetition rate of conventional intermittent motion-picture cameras has a practical upper limit of 250 frames per second. With this type of camera the film must be stationary when the shutter is open, then rapidly advanced to bring the next frame into position for the succeeding exposure cycle. Although applicable to certain moderately rapid mechanical motions, this camera is to a high-speed camera as a magnifying glass is to a microscope.

High-Speed Cameras: Prism-compensating high-speed motion picture cameras are truly "time microscopes." These cameras cover a range of speeds from 150 to 16,000 frames per second. This type of camera uses a revolving glass prism and shutter assembly to shift the image intermittently, but in synchronization with the film as it runs continu-

ously past the lens. The film literally explodes through the camera and is "eaten up" at rates as high as 200 feet per second.

Two prism-compensating high-speed motion-picture cameras are currently being manufactured in this country—the Kodak High-Speed camera manufactured by Eastman Kodak Co. and the Fastax camera manufactured by Wollensak Optical Co., both of Rochester, N. Y.

The Eastman camera *Fig.* 1, is a self-contained unit utilizing standard 100-foot rolls of 16-mm film and with a speed range of 1000 to 3200 frames per second. The speed control, consisting of a built-in rheostat, is interlocked with the drive motor to prevent starting under conditions that would result in film breakage. An argon lamp within the camera exposes timing marks on the film for accurately determining the camera frequency.

Two cam-actuated switches are mechanically linked to the film drive mechanism. One switch automatically stops the camera at the end of its run; the other can be externally connected to synchronize actuation of the camera with the event to be recorded. The camera is capable of speeds down to 300 frames per second if input voltage is reduced through the use of a step-down autotransformer.

The Fastax camera manufactured by Wollensak Optical Co., *Fig.* 2, comes in a variety of models. The basic camera holds 100-foot rolls of 16-mm film and is capable of a speed range from 150 to 8000 frames per second. The camera is equipped with a built-in timing lamp operable from either an external oscillator or an ordinary 60-cycle line. A separate control box, called a "Goose," contains all the necessary controls for regulating camera speed and synchronizing starting of the camera with the event to be photographed. An 8-mm version of this camera is available with speeds up to 16,000 frames per second. Fastex cameras are also available that will handle 35-mm film and 250-foot rolls of 16-mm film.

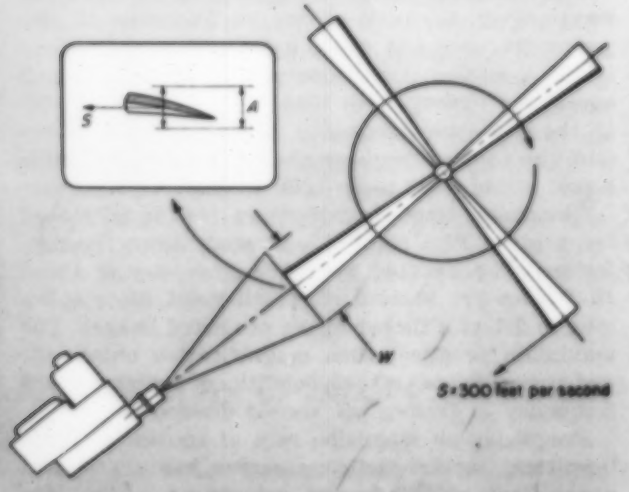
Usually, 16-mm high-speed cameras are preferred by industrial users. This film size is accepted as the standard for most industrial motion-picture work. High-speed films meet the same standards as conventional motion-picture films and can be shown on standard projection equipment.

Camera Speeds: The majority of industrial applications do not require camera speeds in excess of 3000 frames per second. At increased camera speeds the task of lighting the subject adequately becomes progressively greater, *Fig.* 3. Heat generated by the intense photographic lights is a constant problem. Often heat is the limiting factor in establishing a maximum camera speed for subjects comprised of heat-sensitive materials.

Just what does 3000 frames per second mean in terms of retarded motion? Imagine a jet aircraft streaking through space at the velocity of

Fig. 3—Left—Lighting used for photographing lawn-mower cutting action includes direct and reflected sunlight plus incandescent lamps

Fig. 4—Below—Top view of test setup for photographing vibration of the tip of an experimental helicopter blade



sound. The high-speed camera operating at a rate of 3000 frames per second will slow this action down to an apparent velocity of 3 miles per hour—ordinary walking speed!

Take another example—rotational velocity this time. A shaft on a synchronous motor rotates at 3600 rpm. Photographed at 3000 frames per second and projected onto a screen at a projector frequency of 15 frames per second, the rotating shaft appears to make one revolution in 3⅓ seconds. The film record consists of a series of individual pictures showing the progressive movement of the shaft in time increments of ⅓-millisecond and angular increments of 7.2 degrees.

Effective shutter speed for an individual frame is inversely proportional to picture frequency. The proportionality factor is 1/5 for both the Kodak and Fastex cameras. This factor multiplied by the reciprocal of picture frequency in frames per second gives the effective shutter speed in seconds. In the example cited above the shutter speed would be 1/15,000 second and the shaft movement during the time the shutter is open would be 1.4 degrees.

Practical Running Speed: In practice, a 0.002-inch blurring of the image is tolerable. This is roughly 0.5 per cent of the frame width. Applied to the subject field, the movement of the object being photographed during the interval that the shutter is open should be no more than 0.5 per cent of the field width covered by the lens. This fact is the basis for the following equation:

$$R = \frac{500\,S}{W} \cos\theta \qquad (1)$$

in which R = repetition rate (or picture frequency), frames per second; W = field width, inches; S = subject velocity, ft per second; and θ = angle between the line of motion and the film plane, degrees. Equation 1 is used to determine the minimum camera repetition rate for a given subject velocity and field size.

Engineers frequently ask the question, "Yes, we know the action can be adequately slowed down, but is the amplitude of the motion we want to study great enough to be detectable on the film?" The answer to this question is "yes" if the subject movement is greater than 1 per cent of the field width covered by the lens. This relation is expressed by

$$A = \frac{W}{100 \cos\theta} \qquad (2)$$

where A = minimum measurable amplitude of motion, inches; and W and θ are the same as for Equation 1.

To illustrate use of these equations, a hypothetical problem will be outlined and solved. In this problem, we are trying to detect and measure the vibration frequency at the tip of an experimental helicopter blade. Assume the linear velocity of the blade tip is 300 ft per second. The camera is set up with its optical axis in the plane of the blades and intersecting the axis of rotation at an angle of 90 degrees, *Fig.* 4. The tip of each blade in succession moves through the camera field.

Vibration being investigated occurs in a direction perpendicular to the camera axis, but parallel to the propeller shaft. Assume that maximum camera speed obtainable under the existing lighting conditions is 3000 frames per second. What mini-

Fig. 5—Acceleration characteristics of high-speed cameras, which depend largely on individual camera characteristics and voltage regulation in the power-supply line. Other camera curves may not coincide exactly with these

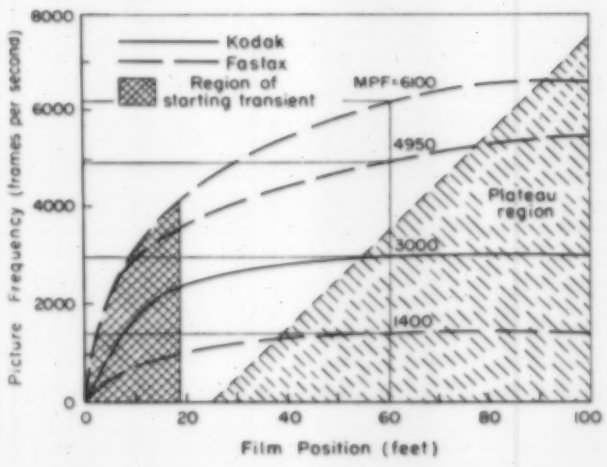


Fig. 6—Projection technique which permits close analysis of the projected image without obscuring the picture. Projector controls are close at hand, and reflection from the mirror corrects image reversal which would be caused by projecting directly on the back of the translucent screen

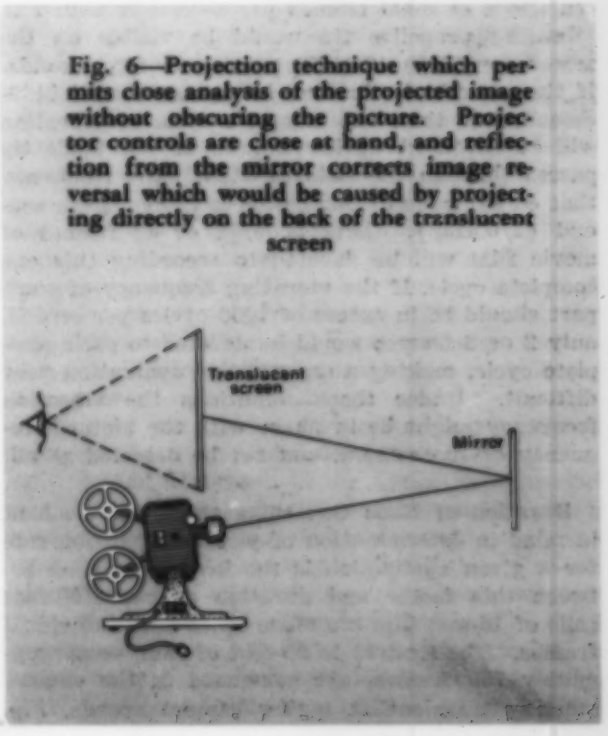


Fig. 7—Simultaneous recording of electrical and mechanical characteristics of a solenoid. Mechanical action is registered on a dial gage. Electrical characteristics are measured by photographing an oscilloscope trace (right side of photo) by using an optical beam splitter

mum amplitude of vibration can be evaluated under these conditions? What practical limits of frequency of vibration can be clearly resolved?

By applying Equation 1 the field width W can be determined:

$$W = \frac{500\,S}{R} = \frac{500(300)}{3000} = 50 \text{ inches}$$

Substitution of this value into Equation 2 gives

$$A = \frac{W}{100} = \frac{50}{100} = 0.5\text{-inch}$$

which is the minimum amplitude of vibration that can be observed. The blade tip would pass through the camera field in about 13.9 milliseconds, since

$$\text{Time} = \frac{W}{S} = \frac{50}{12(300)} = 0.0139\text{-second}$$

Maximum time magnification afforded by a camera speed of 3000 frames per second is 200. The vibrating propeller tip would be visible on the screen for (200) (0.0139) seconds or 2¾ seconds. If the period of vibration is greater than 0.0139-second, less than one complete cycle of vibration will be captured by the camera as the blade tip passes through the field of view. The frequency that corresponds to this period is 72 cycles per second (1/0.0139). About 3000/72 or 42 frames of movie film will be devoted to recording this one complete cycle. If the vibrating frequency of some part should be in excess of 1000 cycles per second, only 2 or 3 frames would be devoted to each complete cycle, making a quantitative evaluation very difficult. Under these conditions the vibration frequency might be in phase with the picture frequency of the camera, and not be detected at all.

Duration of Run: One thing that must be kept in mind in determination of picture repetition rate for a given application is the inverse relation between this factor and duration of run. 100-foot rolls of 16-mm film are made up of 4000 individual frames. The first 15 to 25 feet of film, or approximately 750 frames, are consumed in the camera starting transient at higher camera speeds, *Fig.* 5. A true plateau in the acceleration curve is not reached in the first 750 frames, but the picture frequency after 750 frames is sufficiently constant for most analytical purposes. That leaves about 3250 frames to record the action.

Approximate duration of an event that can be recorded on usable film is obtained by dividing the mean picture frequency into these remaining 3250 frames. Mean picture frequency refers to the picture frequency at the midpoint of the usable film strip, or at a point about 60 feet from the beginning of the film. Mean picture frequency (*MPF*) is a more useful expression of picture repetition rate for a given film record than the often-used maximum or terminal frequency. At speeds less than 3500 frames per second the two values are practically identical. As an example of the above relation, the effective duration of run at a camera speed of 3000 frames per second would be 3250/3000 or about 1 1/10 seconds.

When the event must be synchronized with the camera, an allowance must be made for the camera starting transient. This duration can be roughly determined by dividing the mean picture frequency (in fps) into 2000. At 3000 frames per second for instance, 2000/3000 or 0.67-second is required to bring the film up to suitable speed.

Certain critical applications may require a relatively constant picture frequency. The usable film record under these conditions is restricted to the plateau region of the film acceleration curve. *Fig.* 5. These applications are rare, because with timing marks exposed on the edge of the film, a constant film speed is not a prerequisite for an accurate time evaluation. The time duration of the plateau region is inversely related to the picture frequency, making synchronization very difficult at high taking speeds.

Length of film consumed in reaching the beginning of the plateau is approximately

$$L = 0.01\,R + 25 \qquad (3)$$

where L = length of film to reach plateau, feet; and R = picture repetition rate, frames per second. This relationship is only approximate, since each camera displays its own individual acceleration characteristics. Variation in picture frequency

might be as great as 25 per cent over the "plateau" region given by Equation 3.

The plateau extends to the trailing end of the film or $(100 - L)$ feet. At a picture frequency of 3000 frames per second, 55 feet of film are consumed in accelerating the film to running speed. Length of the plateau is 45 feet. Since there are 1800 frames in 45 feet of film, duration of run at maximum speed is 1800/3000 or 0.6-second. At a picture frequency of 7500 frames per second the plateau is nonexistent.

Projection and Auxiliary Equipment: Interpretation of the projected results is facilitated by using a projector that is reversible and that can be stopped for single frame projection. With equipment of this type localized portions of the film can be run back and forth or stopped for more detailed study. It is possible to splice several feet of film into a continuous loop and achieve the same result without manually recycling the action.

Quantitative interpretation is made easier by superimposing horizontal and vertical lines on the projected image. This can be achieved by painting a grid onto a large sheet of white paper which serves as the screen. A more convenient method of analysis is made possible by projecting the image onto a translucent screen that can be observed from the opposite side, *Fig.* 6. The projected image in this case is not obstructed by shadows cast by those observing the film.

A special instrument has been developed by Vanguard Instrument Corp. to permit accurate evaluation of high-speed motion pictures. This instrument, in which the film can be either manually or automatically transported, utilizes movable crosshairs and a rotatable projection head for obtaining accurate linear and angular measurements. A mechanical counter records the frame number that is being observed. Timing marks on the edge of the film are visible to the observer, so that the precise relation between image displacement and time can be determined.

For most applications a 60-cycle excitation source is sufficiently accurate for timing the event. Under this condition the timing marks will be produced at 1/120-second intervals on the moving film. At 3000 frames per second, the spacing between successive marks is 25 frames. If the exciting frequency is in the form of a sine wave, the individual marks will not be critically defined at the two ends. A square-topped wave of higher frequency is preferable for applications in which extreme precision is required.

PLANNING PRODUCT DEVELOPMENT USES

In an effort to pinpoint areas for the planned use of high-speed photography in product development, a hypothetical program will be outlined. Attempt will be made to touch upon divergent phases of the subject, as faced by both large and small companies in widely dispersed fields. The outline is presented, not as a pattern to follow, but more as a systematic tabulation of ideas to draw from and apply to particular problems.

Basic Research: Substantial portions of the basic data that the designer relies upon in designing the product may be derived from high-speed photographic studies made during research phases of the project. Film records obtained by this technique may be further interpreted to gather specific design information not otherwise available.

As a practical example, build-up of stresses in transparent plastic models undergoing dynamic loading have been studied by combining photoelastic stress-analysis methods and high-speed photography. Problems involving impact, vibration and stress are a frequent target for the high-speed camera.

Photographic investigation of rapid chemical reactions, flames and explosions has provided a potent source of information for many diversified industries. One example is the highly successful experimental studies on knock or autoignition in gasoline engines.

Photography has been applied to the study of air flow through blowers and electric motors, not to mention wind-tunnel studies on airfoil sections. Usually smoke is injected into the air stream to trace out the streamlines. Similar techniques have been employed in hydraulics, where colloidal suspensions of double-refracting materials are added to water and then photographed through circular polarizers. Shear-stress lines in the fluid are thus made visible for analysis. In this same area, high-speed photography has been used to investigate the damaging action of liquid cavitation in pumps and ship propellers and the boundary conditions existing in transition from laminar to turbulent flow.

Idea Appraisal: Assume that the proposed product is a mechanism of some sort with rapid-acting mechanical parts. The first task of the engineering group is to assess the generalized or "first-idea" specifications in terms of specific design feasibility.

One of the basic steps in this program might be to test competitive products and evaluate them in terms of the proposed design. The engineering team assigned to this job must correctly evaluate this data in terms understandable to a nontechnical management.

In what way does high-speed motion-picture photography fit into this picture? High-speed films may reveal imperfections in competitive product performance and point the way toward improved design. By observing the action of competitive models in acute detail the engineer can more accurately assess the functional characteristics of critical components. Moreover, the films are a permanent record of the mechanical action in its simplest form—understandable in most cases even to a nontechnical observer. These pictures, prop-

erly presented to management, can pave the way for a more complete understanding of the problem and leave less room for doubt in making the final managerial decision.

Depending upon the extent and nature of the basic idea, it may be necessary to construct actual working models to test out basic theories. At this stage it is important to derive every last bit of information from an experiment. High-speed photography is invaluable in this phase of the investigation because it not only slows down actions so that they can be analyzed, but records them permanently for others to see and comment on.

Design Studies: After the full-scale design and development program is started, mock-ups comprising various critical components of the machine may be designed and tested. Here, drawing board theories are inexpensively proved or disproved.

Photographic motion analysis applied to the study of high-speed components in the mock-up stage can provide the engineer with design data obtainable no other way. In some cases these models become, in effect, specialized laboratory instruments more complex than the proposed product itself, with provisions for precisely varying and controlling dimensions, position, stress and actuating velocities of component parts, along with inherent means for measuring results.

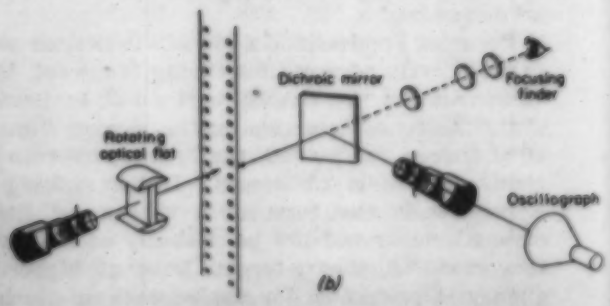
Carefully set up experiments of this type, in which various parts of the mock-up are altered in sequence and photographed in action, result in quantitative records. Precise design criteria can be obtained in this manner along with information that is invaluable for the establishment of preliminary specifications and tolerances.

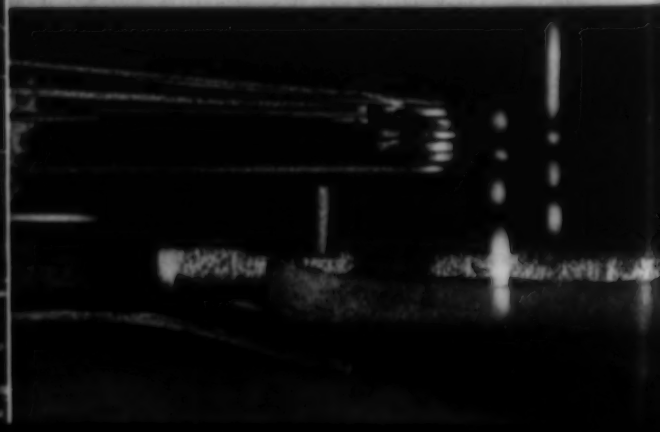
It may be found advisable at this point to determine experimentally the velocities and accelerations certain crucial parts are subjected to in the design. These factors can be accurately determined from the original film record by taking measurements from successive frames on the film. High-speed photography is particularly valuable when the motion is nonperiodic or transient in nature. *Fig.* 7. Under these conditions stroboscopic light techniques are difficult, if not impossible, to apply. Quantitative data obtained makes it possible to calculate centrifugal and inertia forces, dynamic stresses, synchronization between components, actuation times, and duration of certain operations.

A cigarette lighter manufacturer, developing a new type of spring-actuated lighter mechanism, for example, employed high-speed photography to advantage at this point in the design program. A specific correlation between spark intensity and such contributing factors as flint-wheel velocity, flint pressure, flint and wheel alignment, and wheel diameter were required as a prerequisite to finalizing the design. A special machine was designed to simulate the action of the proposed lighter mechanism. The device was constructed so design parameters could be varied with considerable flexibility.

High-speed films made it possible to observe the spark scintilla growth patterns in acute detail. Erratic movements of the wheel as teeth dug into the flint were also disclosed by the camera. The importance of a large wheel diameter, a controlled acceleration characteristic, and a loosely fitting wheel-arbor became evident as a direct result of these experiments. An interesting quantitative study of the films clearly indicated that the spark-formation process is explosive in nature. The individual burning flint particles are not thrown off of the wheel by centrifugal force, as one might

Fig. 8—Method used with the Kodak 16-mm camera to photograph electrical contact bounce and a simultaneous oscillograph trace, *a*. The oscillograph trace, *b*, is projected through the back of the film. An actual film frame, *c*, carries both the visual record and oscillograph trace





expect, but have velocities much in excess of the peripheral velocity of the wheel.

The problem may be to determine the magnitude of dynamic strains in certain critical components of the mechanism at this stage. Measurement of inertia forces on certain components may be facilitated by attaching an accelerometer to the part and recording the action with the high-speed camera. The accelerometer may be nothing more than a small weight supported on the end of a flexible leaf. The opposite end is securely attached to the body undergoing acceleration. Magnitude of deflection in the shaft is a direct function of the accelerating forces at the point of connection.

A more rigorous determination of dynamic strains is possible using electrical strain gages cemented to the component. A high-speed camera with a streak attachment makes it possible to simultaneously record on the same film the actual event and the oscillographic pattern transmitted by the strain gage. Streak attachments are available for both the Kodak and Fastax cameras. An entirely separate optical system is used to record the oscillographic trace. The continuously moving film provides the time base. With the Kodak camera the oscillographic record is projected through the back of the film, *Fig.* 8, and is superimposed on the image produced by the normal taking lens.

In this same general field of instrumentation, the high-speed camera has been used quite successfully to record rapid movement of instrument needles and liquid levels in manometers. Maybe a certain dynamic pressure effect needs to be recorded. A simple manometer photographed in action may provide the answer.

Obviously this method is most applicable to low-pressure disturbances. High-pressure transients are best studied photographically by recording the deflection of a flexible diaphragm in the pressure chamber. A mirror cemented to the diaphragm can be used to reflect a narrow beam of light onto a scale several feet away. A second mirror attached to an adjacent, nondeformable section of the pressure chamber can be used to reflect an "index spot" onto the scale. This averts any trouble from relative movement of the light sources, pressure chamber and scale. The high-speed camera would be used in this setup to record rapid movement on the scale of the spots of light.

As a practical example of photographic recording, the Forest Products Laboratory of the United States Department of Agriculture's Forest Service employed high-speed photography to record dial indicator readings in connection with rapid loading tests on wood. In a typical setup, *Fig.* 9, 20 dial readings showing deflection of the specimen were required within 1/10-second. A clock making one revolution per second was included in the field of view, revealing on each individual frame the relation between the time factor and the dimensional displacement evident on the gages.

Prototype Testing: So-called "bugs" are prevalent in any first model of a new design. If the mechanism is a rapid-action device, these "creatures" can become very elusive indeed! Slow the mechanical action down, so it can be seen, and the defects disappear. Speed it up again, so everything is a blur like it's supposed to be, and the trouble reappears. With the high-speed camera, functioning of critical parts can be observed when the machine is operating at its optimum speed. Guesswork isn't necessary. Precise visual data is available upon which to base a decision.

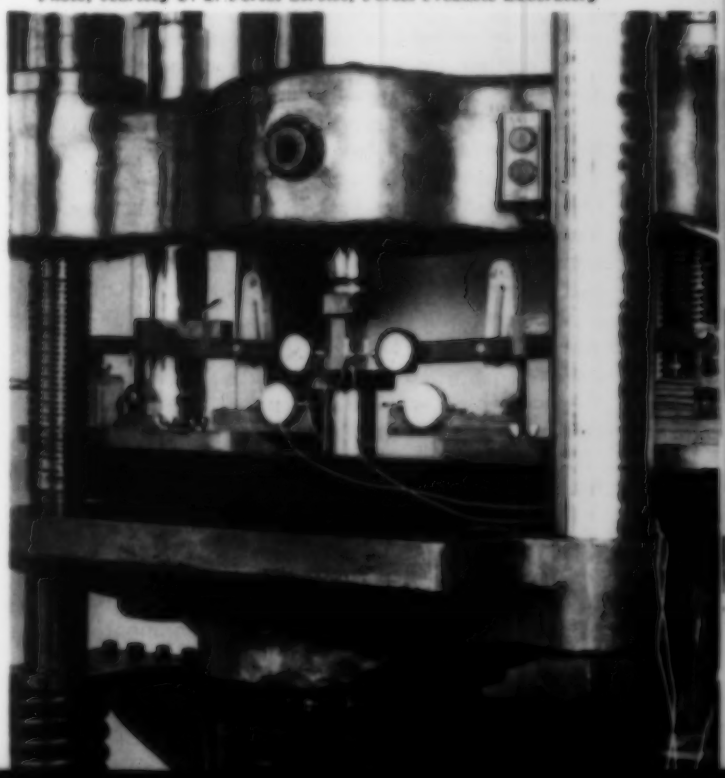
For high-speed motion picture photography to be effective, the parts causing trouble must be visible to the camera. Again, careful planning pays off. If trouble is anticipated within a certain component of the machine, provision should be made for visual access to this region if possible. In most cases a clear plastic window serves the purpose. If later insertion of a window entails a major dismantling job, a lot of time and expense can be saved by anticipating the need for a transparent port and providing it in the prototype machine as a design feature.

Potential design or constructional weaknesses can often be discovered in a prototype model by the exploratory use of high-speed photography. These imperfections may lead to a premature breakdown, or if the tolerances are not sufficiently close, a continuous malfunctioning of subsequent models. It may be advisable to survey all critical areas with the high-speed camera strictly as a precautionary measure.

A Midwest manufacturer of automatic produc-

Fig. 9—Test setup for recording dimensional changes in wood due to dynamic loading. Twenty readings were required within 1/10-second, obtained with high-speed photography

Photo, courtesy U. S. Forest Service, Forest Products Laboratory



tion machinery had trouble with one of his prototype model machines and high-speed photography was employed to help locate it. Several films were taken of the general area in which the trouble existed. In analyzing these films, not only was the immediate problem solved, but two other defects were detected that could have resulted in malfunctioning at a later date.

Pilot Run: Close co-operation between the designer and the process engineer is an important prerequisite for success during the pilot run. Manufacturing problems are certain to arise which may result in a request for changes in material or dimensional specifications. Certainly, before changes are authorized, every effort should be exercised to remedy the difficulty at the source. Again, high-speed photography deserves attention as a technique applicable to this task.

High-speed photography can be depended upon to aid in the observation of almost any manufacturing problem that is normally a blur to the eye if the area to be studied is accessible to the camera. Mirrors may be necessary in order to gain optical contact with the region under investigation or to reflect light into dark areas. Some production processes, such as certain metal-spinning and extrusion operations, are self-luminous and do not require additional lighting. Arc-welding processes, for instance, have been a frequent subject for the high-speed motion picture camera, particularly in full color. Photographs made in color bring out the multi-chromatic phases of the self-luminous arc that would otherwise be difficult to resolve.

Photographic techniques have been applied successfully to most machining operations, including drilling, tapping, grinding, milling and planing. Other manufacturing processes might involve stamping, drawing and extrusion operations or mixing spraying and pouring actions.

In setting up the high-speed camera study, all the necessary information for eventual analysis should be recorded—either on the film or on paper. It pays to make a careful preliminary analysis of the operation to be certain that all critical areas are covered by the test. It may be advisable in some instances to scribe reference lines on deformable parts or to put index marks on movable components. Pieces that run continuously through a machine might be conspicuously numbered or marked so that they can be compared with the film record when the final analysis is made. It is difficult to anticipate just what the photographs will disclose. Having the actual pieces on hand for physical analysis and direct comparison with the film record often eliminates guessing.

Final Development Stages: Once the manufacturing aspects of the new product have been proved, all divisions of the company become actively engaged in the final stages of development. Sales literature, instruction books and service manuals are prepared. Consumer or field tests are initiated. Engineering drawings and specifications are finalized. Cost figures are tabulated. A sales training program is instituted. In supplying technical information to these various groups, the designer may find high-speed photography to be a great deal of help.

Take, for instance, the preparation of sales literature and instruction manuals. Quantitative data obtained from the films may form the basis for specific performance figures. If actuation time is a critical factor for a particular product, successive pictures enlarged from individual frames might be used to illustrate the rapidity of action by comparison to similar pictures of a common light bulb bursting or of an electric fan revolving. Or the enlargements might be used to guide the artist in pictorially describing certain high-speed operations. In some instances the prints themselves could be substituted for artist's drawings, and would certainly provide a more factual representation of the motion than the artist could hope to achieve.

A sales training program, designed to acquaint the salesman with the new product, wouldn't be complete without the demonstration of high-speed films, if they are available. What better way is there to gain a fundamental familiarity with the functional aspects of a complex, rapid mechanical action than to actually see it in ultra-slow motion? These same films might be valuable to the sales department as a cornerstone for a sales-promotional movie to be used in dealer training or to be shown before technical societies or the general public.

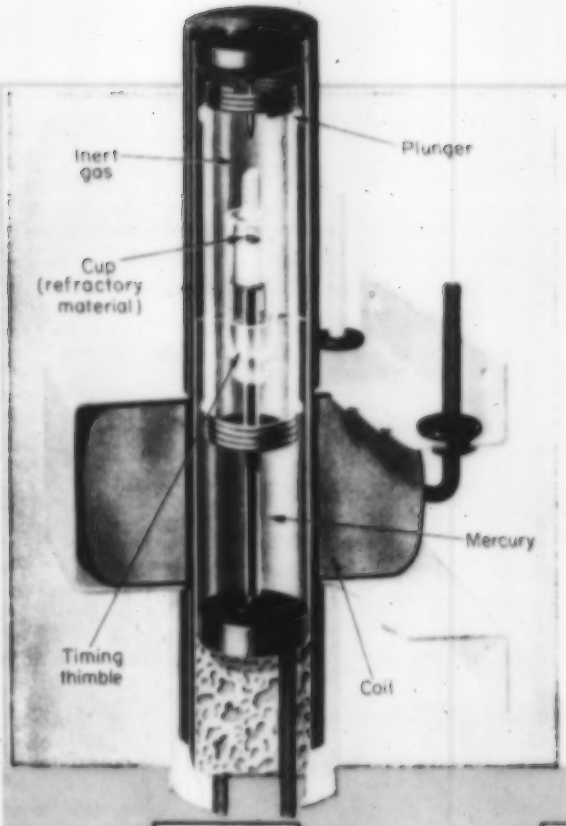
A Chicago manufacturer of electrical switches prepared a 15-minute high-speed motion picture for educational purposes to demonstrate their product in action. Shown before engineering societies and technical groups, this film gives the engineer a concept of the functional details and operating principles that contribute to sound switch design and application. New switches in the company's line were promoted through the use of this medium.

Field tests may uncover constructional or design weaknesses peculiar to only a small percentage of the new-product units. It may be advisable to substantiate these complaints by studying the action of defective units with high-speed photography. These films become a permanent record of the action prior to disassembly, useful as a guide to product improvement.

Availability of production parts makes it possible to test several models of the product assembled from components that cover the entire tolerance range. This verification by experimentation is sound engineering practice in areas of critical dimensioning. High-speed photography can be applied here to reveal conflicting action and general smoothness of operation.

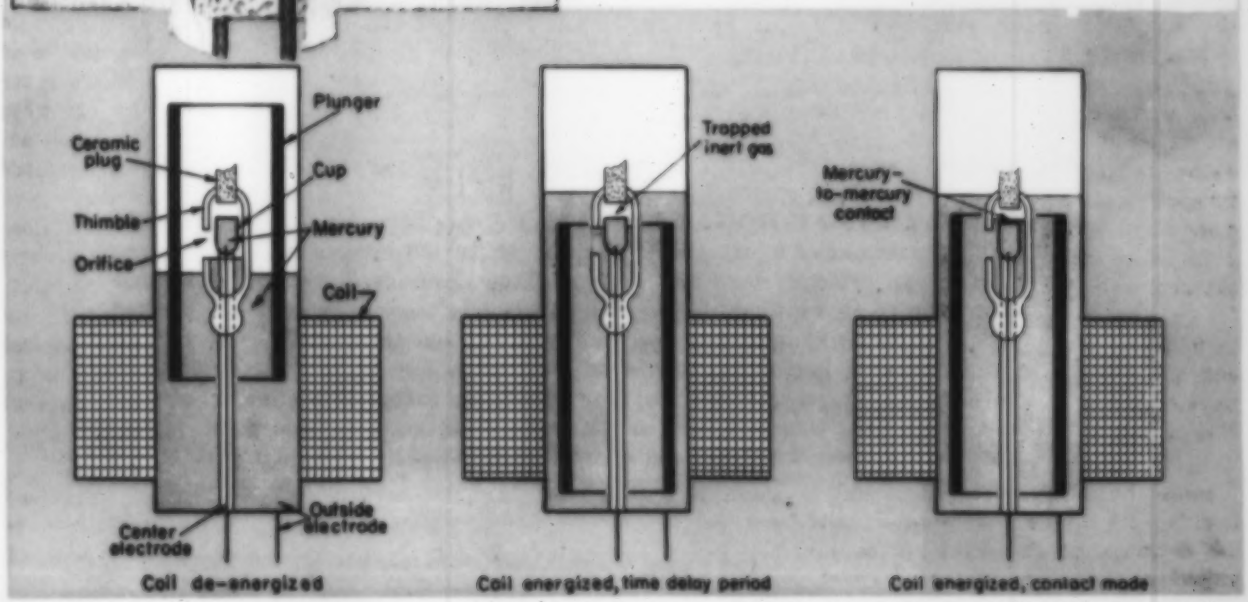
High-speed photography has fertile ground in which to grow in this general field of organized product development. Scope of its application is limited only by the resourcefulness and vision of those who put it to work.

SCANNING the field for IDEAS

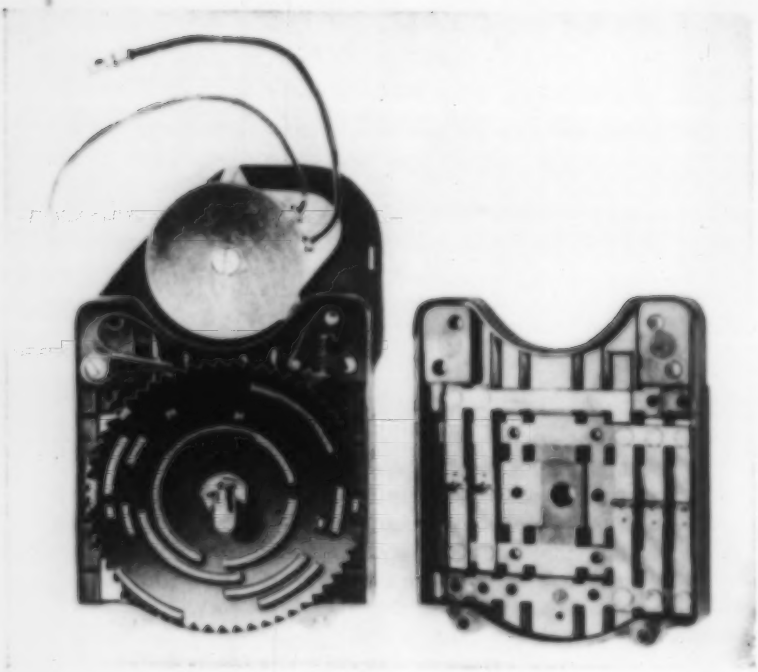


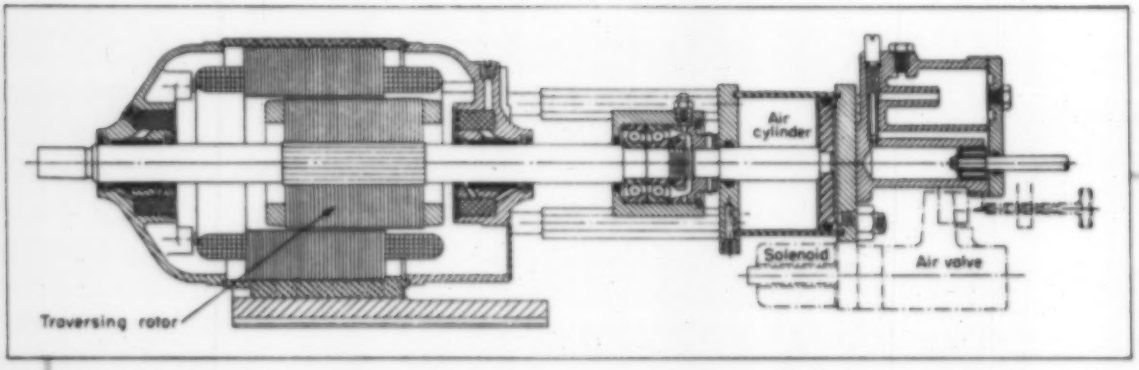
TIME DELAY is controlled by escape of trapped inert gas through ceramic plug pores, in a relay built by Adams and Westlake. Length of delay in this mercury plunger-type relay is determined by porosity of the plug material. Although the period is fixed and nonadjustable, it is immune to normal line voltage fluctuations or effects of ambient temperatures through the range of −38.8 to 200 F.

When the normally open, slow-make relay shown is energized, the coil pulls the plunger down. The plunger displacement causes the mercury level to rise. Mercury enters thimble through orifice and traps inert gas in the space above the orifice entrance. Gradually the mercury displaces the gas which escapes through ceramic plug until electrical mercury-to-mercury contact is made; the center cup of mercury and the outside volume of mercury are connected to the center and outside electrodes, respectively.



SINGLE PLASTIC CAM permits selective programming of several electric circuits in appliance timer designed by the R. W. Cramer Co. Inc. Entire time program is molded on both sides of a rotating shaft-mounted cam. This unique design feature not only eliminates multiple cam keying, but also assures a high degree of timing accuracy and exact repeat cycling. Shallow timer construction which results from using a single thin cam permits easy installation in restricted areas. Controlling up to 12 circuits in a wide range of timed sequences, the timer is driven by high-torque synchronous motor.

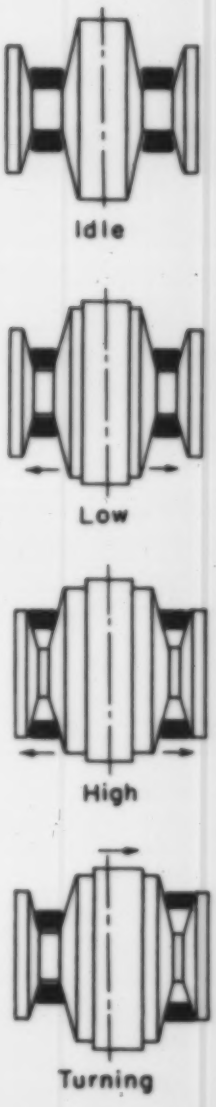


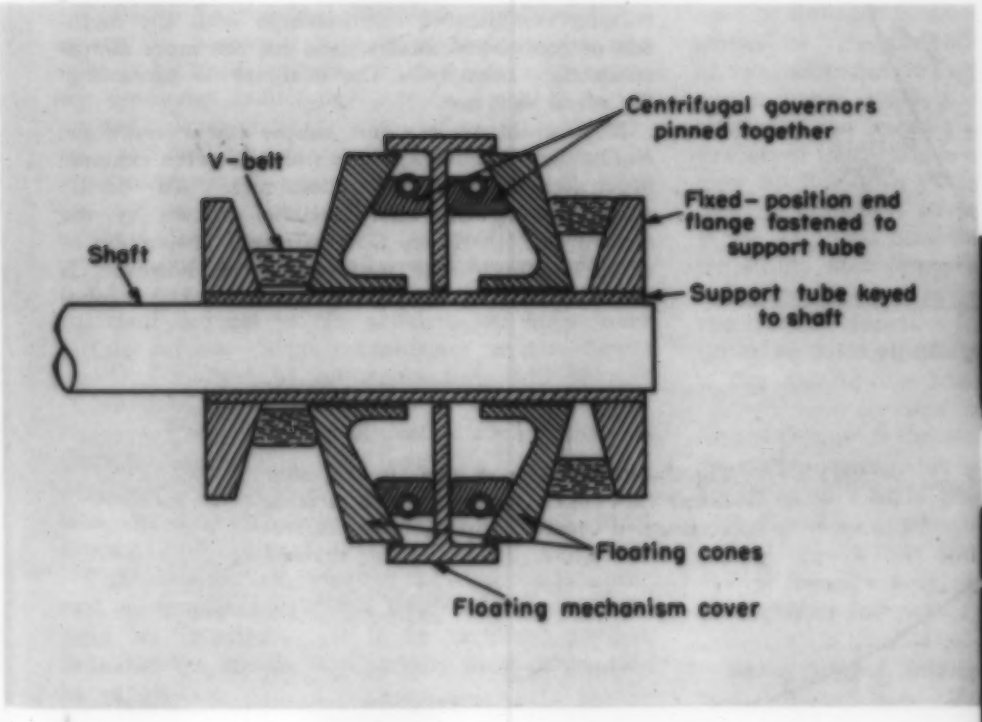


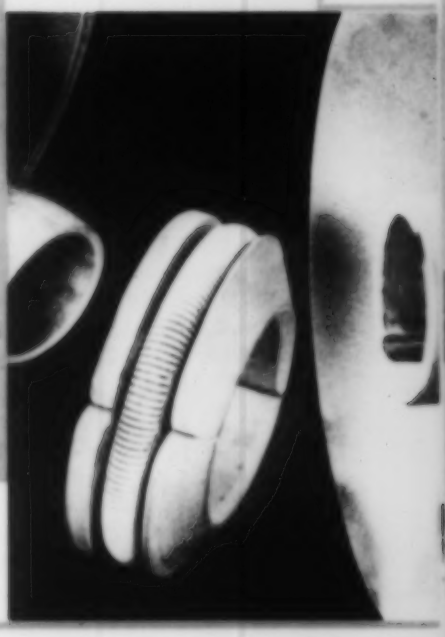
TRAVERSING ROTOR in induction motor simplifies design of in-line drilling units developed by the Black Drill Co. Major advantages claimed for using this design principle here are higher drilling accuracy, lower vibration, and a minimum of working parts. Rotor and shaft are pneumatically shifted by a simple air cylinder through approximately one-third of the rotor length. Torque loss at maximum out-of-field position is only 25 per cent. The unit is designed to provide required horsepower at extreme position of stroke. Additional iron is used in the motor to increase the saturation point, giving rated horsepower when rotor is at maximum out-of-field position.

IDEAS

AUTOMATIC TRANSMISSION for dual V-belt drive uses two centrifugal clutches. Sensitivity to torque as well as speed provides differential action also. A design developed by V-Plex Clutch Div., Light Inspection Car Works, utilizes two variable-pitch sheaves. When the drive operates at idling speed, the belts slip and there is no output. When crankshaft speed reaches the engagement setting, centrifugal governors bear against the floating cones, moving them apart toward the fixed-position end flanges. As speed increases, after load is picked up, added centrifugal governor pressure exerted on the floating cones forces the belts outward toward the maximum pitch diameter of the sheaves. Axial wedging force of the governors is balanced by the wedging force of the belts in the sheaves. Hence, with added load resistance—higher belt tension—the belts force the sheave halves apart, overruling the governor, and drop back to "low gear." Since the central parts of the unit are free to float axially, belts operate at different pitch diameters if belt tensions differ. This feature is useful in dual traction-wheel driven equipment in that each wheel takes its proper share of the load. If one wheel slips, the pulling power on the other one increases.







Complex or nonlinear design problems can often be simplified with an

ANALOG APPROACH

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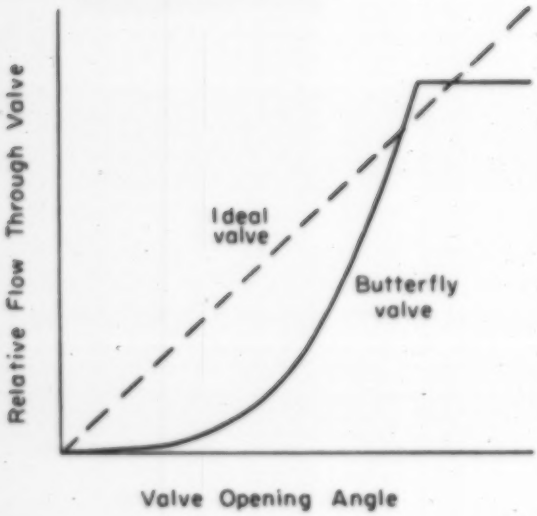
BETWEEN the statement of a problem and its numerical answer lies its method of solution. Certain tools are necessary to effect that solution; some are relatively simple and easy to use, others are complex and require great skill on the part of the operator.

Each problem, depending upon its complexity, requires tools of different caliber. Problems involving simple linear relationships do not require the complex procedures involved in the solution of more complex problems.

Often attempts are made to solve problems involving complicated relationships with the methods or tools successfully used for the more simple solutions. Sometimes the designer is successful, but often he is not.

Most problems are not simple linear relations. Nonlinear relationships, such as the valve example illustrated in *Fig.* 1, predominate. An "ideal" valve, having the characteristics shown by the dashed line, increases flow in direct proportion to valve opening. The butterfly valve, however, is nonlinear. At small openings there is only a small

Fig. 1—Butterfly valve characteristics is an example of a non-linear component



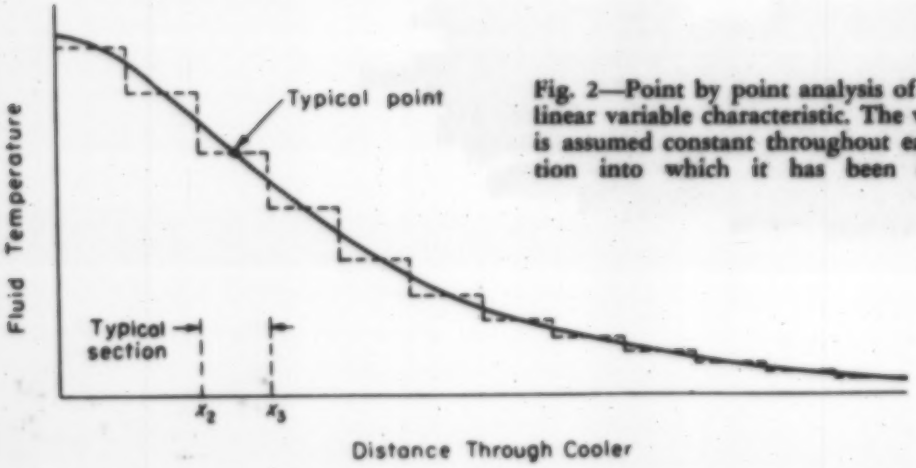


Fig. 2—Point by point analysis of a nonlinear variable characteristic. The variable is assumed constant throughout each section into which it has been divided

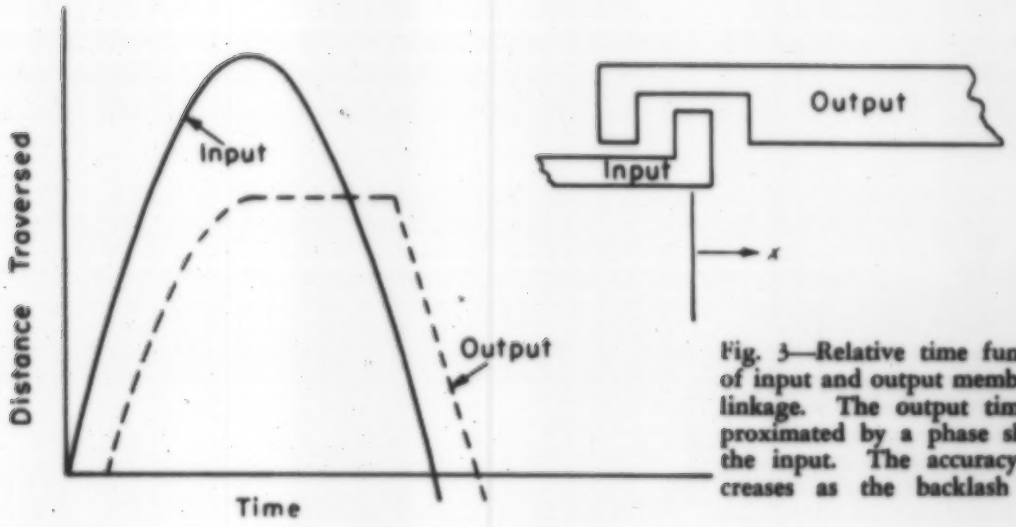


Fig. 3—Relative time functions of the positions of input and output members of a loosely coupled linkage. The output time function can be approximated by a phase shift and attenuation of the input. The accuracy of approximation increases as the backlash distance is decreased

change in flow rate. Finally, a saturation is reached where there is no increase in flow at the widest openings. This discrepancy between ideal linear and real nonlinear observations exists in many fields. A slight reshaping of the butterfly valve curve, for example, would give the characteristic *B-H* curve for a magnetic core.

Several approaches to a nonlinear problem are possible. Some of the methods even though known to be naive, may be used to obtain satisfactory answers in far less time than a more thorough approach.

Possible Approaches: Simplest approach is to ignore the nonlinear aspects of the problem and solve it by linear means. In elementary engineering problems, inductances are assumed to be of constant permeability, fluids assumed incompressible and heat transfer coefficients do not vary. In some cases results are sufficiently accurate. Generally, however, this approach should be confined to the engineering classroom where the student is taught to question and understand approximations.

A more refined approach is to assume that the nonlinear aspects of the problem are linear over certain ranges. Some transformer manufacturers use this method by assuming they will operate on an assumed linear portion of the *B-H* curve. By not approaching the saturation region, they effectively establish a volts per turn value for all windings on the core. However, experience dictates the use of mysterious correction factors when necessary for economic reasons.

This method then consists of a purposely incorrect assumption corrected by results brought to light by experience. It is an excellent method, provided the answer has already been determined by experience.

A third approach involves the assumption that the nonlinear elements are linear for small changes of the independent variable. *Fig.* 2 illustrates a point by point analysis of a nonlinear variable. The variable in each of the minute sections into which the curve is divided can be assumed constant. Equations can be written for a single point in each section and are a good approximation of the entire section. Then solving all the equations and matching up the boundary conditions at points between sections give a series of results which describe the system throughout the entire range of the variable. Obviously, with smaller sections greater accuracy would result.

A recent approach studies the nonlinear element by means of its effect on a sinusoidal change in the input variable.[1] A graphic example of this approach is given in *Fig.* 3. The input to the loosely coupled linkage is sinusoidal; the output is roughly sinusoidal. The method closely describes the effect of the nonlinear linkage by an amplitude change and a phase shift in the output in the manner similar to the transfer function of a linear element. Either or both the amplitude and phase change may be functions of input variable amplitude as well as frequency. From this, a describing function is set up. This describing function illustrates the amplitude and phase change in the form of an operator. The operator is then used along with the transfer function to analyze the circuit by the usual methods of feedback analysis.

The assumption has been made that such an operator can be used, based on a Fourier analysis of the output of the element with sinusoidal input. A further assumption is that all harmonics beyond the first have little effect upon the circuit.

A graphical approach is often quite valuable but almost always long and painstaking. Once a solution is found, a great deal of additional work must be repeated for each parameter change.

Basic Analog Principles: The basic analog approach is not new. For example, ship models are built to test new hull designs rather than building a full-scale vessel. Observation of the scaled-down analogy of the proposed vessel yields performance

[1]References are tabulated at end of article.

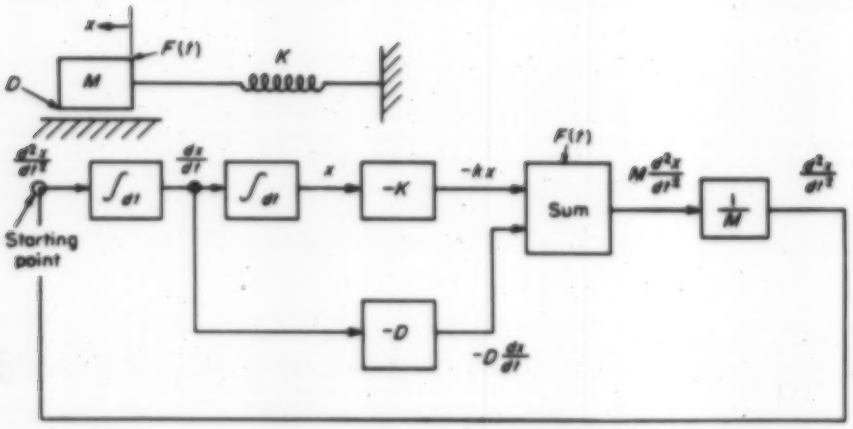


Fig. 4—Right—Simple mass, dashpot and spring system, above, and a block diagram of its simulation by the analog method, below

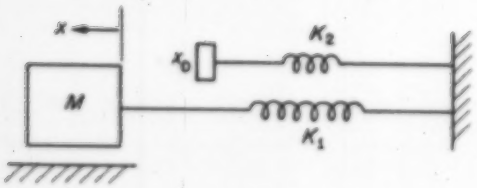


Fig. 5—Below—Nonlinear spring simulator. Mass M engages the second spring K_2 after moving the distance x_0

data under conditions analagous to those the ship will be expected to face.

With models, the model builder makes the assumption of linearity. He assumes that if he reduces all dimensions in proportion and tries proportionally small disturbances, he can project his answers back to full scale. People who used this particular analog approach have learned a good deal from experience. In application to a new field, however, a question of accuracy might be raised, and thus an alternate analog approach is suggested.

This alternate approach is, in a sense, a full-scale model. Various elements and variables of the analog, however, no longer resemble the device in form. In particular, the electric analog computer uses voltages whose magnitudes are the analogs of variables and uses resistors, capacitors and inductances as analogs of the original elements.[2]

Some of the more basic principles of analog computation are quite obvious. A potentiometer, for example, with a voltage impressed across it and a voltmeter between one end and the moveable brush is actually multiplying the input voltage by a ratio of resistors. The voltmeter reads an output voltage which is the product of the input voltage and the ratio. Suppose the input voltage is made analogous to acceleration, the potentiometer setting analogous to mass and the output voltage analogous to force. The result is a rather useless analog computer which, for any given mass, will tell the force necessary to cause various accelerations. Also, for a given acceleration the potentiometer can be adjusted to find the mass that will be given this acceleration by a particular force.

Among the other basic parts of an analog computer are amplifiers for multiplication by a constant greater than 1. Cathode followers may be required to prevent loading of potentiometers. Special feedback circuits around basic amplifiers give quite accurate integration and differentiations of voltages with respect to time.

Applying Analog Principles: An example of a simple linear problem is the classical mass, dashpot and spring problem. A mass M resting on a plane, *Fig.* 4, with which it has a viscous damping coefficient D, has its motion restrained by a spring of constant K. The well known equation of motion is:

$$M\frac{d^2x}{dt^2} + D\frac{dx}{dt} + Kx = F(t)$$

where x is the displacement and $F(t)$ is the driving force.

From an analog computer standpoint, the solution to the preceding differential equation would proceed as shown in the block diagram of *Fig.* 4. Blocks $-D$, $-K$ and $1/M$ are multiplying amplifiers. Two electronic integrators precede the $-K$ amplifier. A summing amplifier adds $-D(dx/dt)$ $-Kx$ and $F(t)$.

Referring to the diagram of *Fig.* 4, solution of the problem is as follows:

1. A starting point is selected and a voltage analogous to d^2x/dt^2 is assumed to appear there.
2. This voltage is integrated with respect to time, giving dx/dt.
3. A second integration results in x.
4. Factor dx/dt is multiplied by the constant value $-D$.
5. Factor x is multiplied by the constant $-K$.
6. Results of steps 4 and 5 are added to the input, $F(t)$, which results in a voltage analogous to $M(d^2x/dt^2)$.
7. Multiplying this last found voltage by the constant $1/M$ gives d^2x/dt^2 which is the assumed voltage at the starting point.

Closing the loop as described results in a computer which will solve that differential equation. Now the parameters M, D and K can be varied. Time change of the position, velocity and acceleration of the mass can be observed with an oscilloscope.

The foregoing problem and its solution are linear. One type of nonlinearity that might be encountered in practice is to have the mass M encounter a second spring after it has moved through

part of its travel. Such an arrangement is illustrated in *Fig.* 5. Mass M engages spring K_2 after traveling distance x_0.

From an analog point of view, all components of the system being studied are considered from their effect upon the variables. Thus, a spring is a force-producing device into which a position is fed. Out of this spring comes an output force which is a function of that position.

A plot of output force against input position gives a spring rate having a slope K. Having the mass pick up an additional spring at some point x_0 is the same as having one spring whose relationship has a slope K, up to x_0, and a different slope K_2 thereafter. K_2 then represents the combined spring rates.

Before simulating this non-linear effect, it is necessary to consider first the basic operational amplifier used in analog computers. A block diagram of such an amplifier is shown in *Fig.* 6. Two assumptions are necessary: (1) the gain of the amplifier is very high, and (2) the amplifier draws no current from any source. Z_1 and Z_f are the impedances of the input and feedback circuits and e_g is the voltage at the input grid of the amplifier. All voltages are measured to ground. A mathematical derivation based on laws of current flow results in the following equation for overall gain of the unit:

$$\text{Overall gain} = \frac{Z_f}{Z_1}$$

The approximate output voltage can be written as:

$$e_{out} = -\frac{Z_f}{Z_1} e_{in}$$

This type of operational amplifier is used for multiplication by coefficients greater than 1. It multiplies by a negative constant.

To adapt this basic amplifier to simulate the combination spring problem, a high-ratio diode is added in parallel with the feedback loop as illustrated in *Fig.* 7. Thus, inputs of one polarity would be multiplied by an overall gain of Z_B/Z_1 and those of opposite polarity by an overall gain depending upon the parallel impedance of Z_A and Z_B. One possible representation of the input vs output relationship is shown in *Fig.* 8.

At this point in the construction of the computer, the distance x_0 must be added. To accomplish this, a constant bias is added to the input. Bias voltage C is analogous to the distance x_0. Then, the actual signal voltage feeding the amplifier represents $x - C$ rather than x. The output is also biased to make zero output for zero input. Final output vs input relationship is shown in *Fig.* 9.

With the proper arrangement of the biased operational amplifier, the damping characteristic D might also be a function of velocity rather than a constant.

Generally, the biased operational amplifier with diodes in the feedback can be used to simulate an $f(x)$ vs x relationship which consists of straight-line sections connected at distinct points of slope change. Most interesting is the simplicity with which these relations may be set up. All parameters and the slopes between them can be simply adjusted.

Such simple nonlinearities do not really demonstrate the advantage of the analog approach. These nonlinearities can also be handled by more tedious but more accurate methods. In the case of the analog method, however, adding simple nonlinearities to a particular problem only increases the complexity of its solution by additional electronic gear. On the other hand, the tediousness of the analytical solution seems to go up as a power of the number of simple nonlinearities in the problem.

Although only one simple nonlinearity has been described, the method is equally applicable to many others. For example, it may be applied to problems involving stops (elastic and nonelastic), backlash and dead zone.[3]

Advantages of the analog approach are better

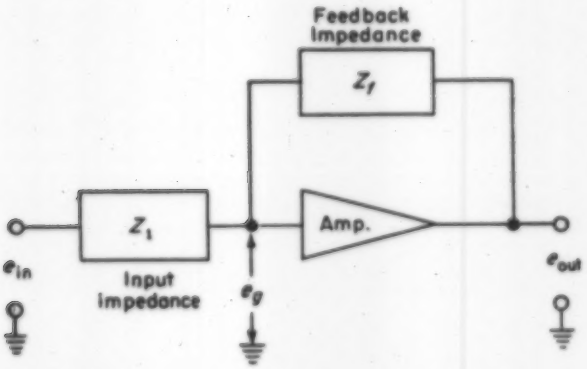
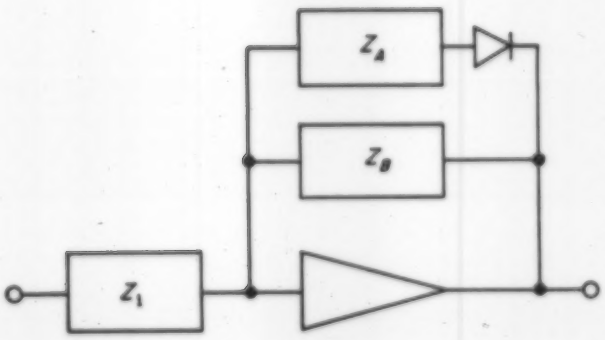


Fig. 6—Above—Block diagram of a basic operational amplifier. Z_1 and Z_f are the input and feedback loop impedances that determine the output characteristics of the amplifier

Fig. 7—Below—Block diagram of a basic operational amplifier with a high-ratio diode added to the feedback circuit. Its purpose is to make the slope of the output vs input characteristic different for positive and negative signals



demonstrated by considering a more complex nonlinearity. For example, in the system of *Fig.* 4, if the damping coefficient D were a function of the position of the mass an interesting problem would be presented. Such an effect could be caused by the geometry of the mass and surface. In this case the equation would be:

$$M\frac{d^2x}{dt^2} + \frac{dx}{dt}f(x) + Kx = F(t)$$

Here, K could again be a function of x. If the relation between D and x is a continuous one, the analytic solution of this equation could be quite involved.

Referring back for a moment to the simpler problem of *Fig.* 4, a signal analagous to (dx/dt) was multiplied by a constant D and the result, $D(dx/dt)$ fed into a summarizer. In this more complex case a signal analogous to x is fed into a biased operational amplifier with diodes to get $f(x)$.

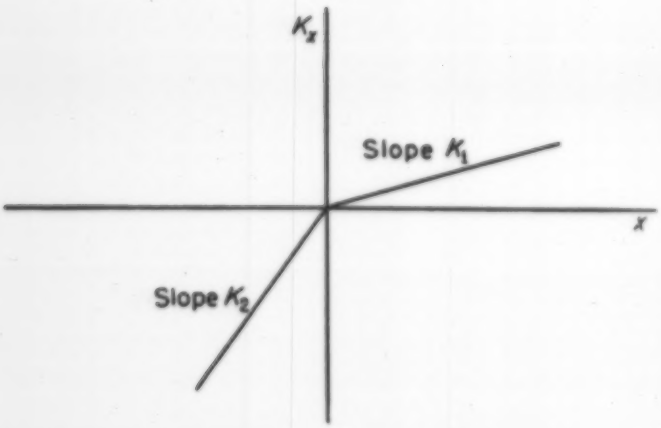
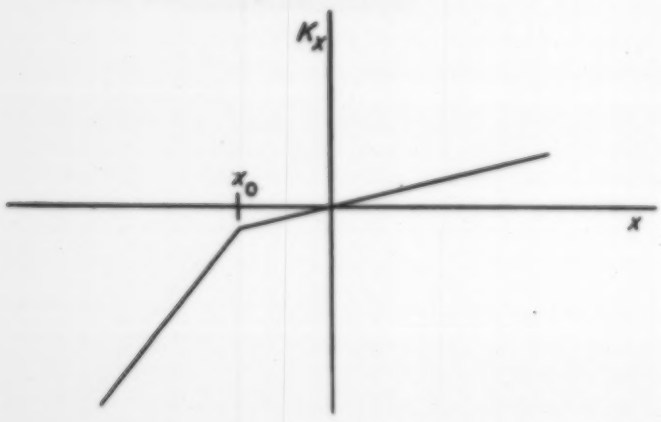


Fig. 8—Above—Output vs. input characteristic of the operational amplifier with diode. Feedback loop impedances Z_A and Z_B determine the difference in slope between K_2 and K_1

Fig. 9—Below—Output vs. input relationship for a biased amplifier. The amount of bias impressed on the input determines point x_0



Then we would multiply the signal representing $f(x)$ by one representing dx/dt. The output of the multiplication would be the $D(dx/dt)$ for this problem.

Multiplication by a constant is merely a matter of multiplying by the overall gain of an operational amplifier. Multiplication of two continuously varying signals is a more difficult problem. There are methods to accomplish such multiplication, but their circuitry is quite involved. One successful method takes the signals to be multiplied and adds and subtracts them. The results, $a + b$ and $a - b$, are then individually squared. Since $(a+b)^2 - (a-b)^2 = 4ab$, multiplying by ¼ gives the answer.

Conclusions: It follows that the direct result of the solution of a nonlinear problem is a numerical answer. This answer may be in the form of a group of time functions, the peak amplitudes of transients, or some similar desired information. Use of the analog method will obtain such an answer and, in addition, reduce the tediousness of the solution.

Each parameter is made available in terms of a knob with a scaled pointer. Results in the form of a time function of magnitude can be instantly available on an oscilloscope.

Various configurations and possible parameter changes are easily and instantly placed into the system. Each parameter can be put through a range of values and the most effective range of each can be then evaluated. Thus, an optimum combination of parameters to achieve a particular desired result can be found.

Solution of any problem must be evaluated in terms of accuracy of result and relative ease of procedure. Increased speeds and closer tolerances demanded of present day equipment often require re-examination of assumptions necessary in solving nonlinear problems. An analog approach is suggested as a successful method of handling these problems.

Limitations occur in the accuracy of an analog computer solution due to the degree of simulation obtainable. However, the overall accuracy can be compared favorably with that of the actual knowledge of the parameter values of the device under study.

Because the analog approach to a problem is based on functional and operational considerations, it can be of greater value than just obtaining a numerical answer. It can give insight into the problem—insight that is perhaps otherwise not available.

ACKNOWLEDGEMENT

The author acknowledges with appreciation the cooperation of R. J. Medkeff, director of computer service, Askania Regulator Co., Chicago.

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Internal Combustion Engines—2

By Keith A. Carlson
Assistant Editor, MACHINE DESIGN

Fig. 31—Nonvolatile fuel and non-poisonous exhaust are plus factors in this small diesel powered materials carrier intended for mining operations

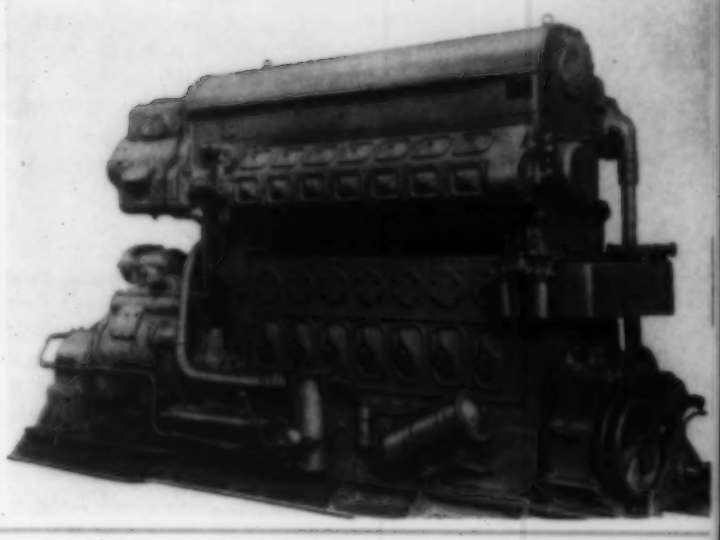
OPERATING principles of both spark-ignition and diesel engines and the characteristics of available types of gasoline engines were discussed in the first installment of this article, which appeared in December. Completing the article, this part includes a discussion of available diesel engines and the factors to be considered in selecting and applying engines of all types. A table summarizes the most important characteristics of U. S.-made engines.

Diesel Engines

General: Undoubtedly the most important characteristic and outstanding advantage of the diesel engine is its low specific fuel cost. This results in part from the lower cost of diesel oil, but even more from the comparatively high thermal efficiency which cuts down fuel consumption. Thermal efficiencies of the order of 35 per cent are commonly attained in diesel engines because of their high compression ratios.

Comparative fuel economy of diesel engines is even better at light loads and speeds less than maximum. Specific fuel consumption remains relatively constant under these conditions while for gasoline engines it tends to increase as load is reduced. Advantages offered by low fuel con-

Fig. 32—Only obvious differences in design between this large diesel engine and those of much smaller size is the number of handhole covers which make servicing, adjustments and many repairs possible with the engine in place. Inspection with the engine running is also possible



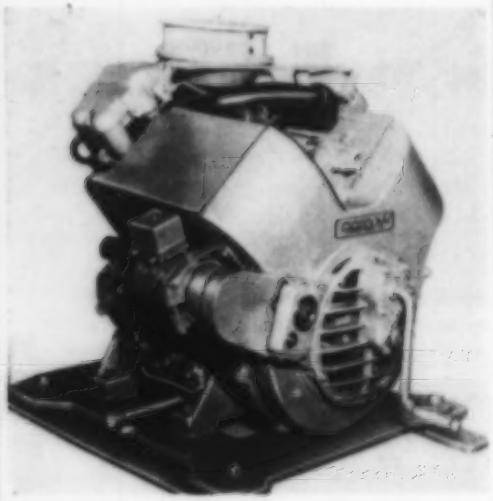


Fig. 33—Small two-cylinder, V-type air-cooled diesel engine develops 13 bhp at 1800 rpm. Weight is 340 pounds. Piston displacement is 72.16 cubic inches

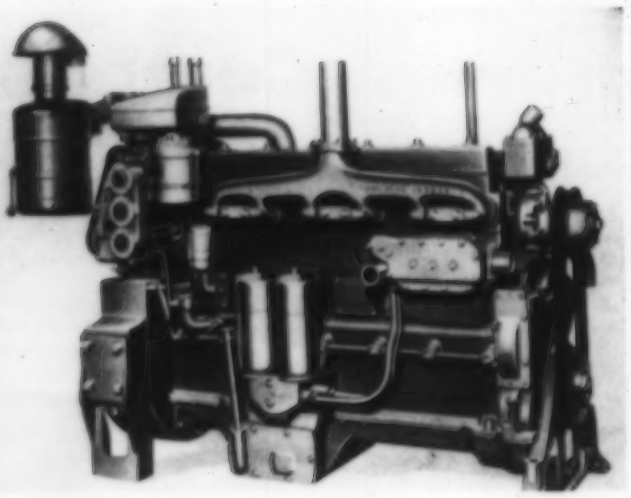


Fig. 34—In-line, 6-cylinder diesel engine delivers 100 bhp maximum, at 1600 rpm. Piston displacement is 525 cubic inches

sumption could, of course, be nullified by high cost fuel. However, diesel fuel costs approximately two cents less per gallon than non-premium gasoline to further compound the diesel's advantage from a fuel cost standpoint.

Diesel fuel is also comparatively safe to handle and store. Although it will burn, it does not vaporize at a rate rapid enough to form an explosive mixture with air.

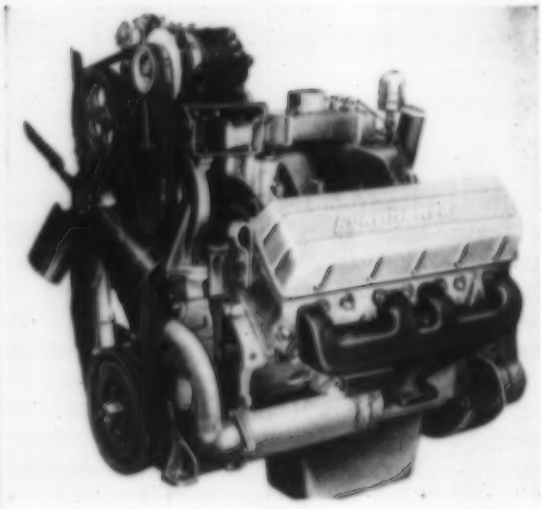
Another advantage of diesel engines for certain applications is that the exhaust gases are usually non-poisonous, *Fig.* 31. This is because there is always excess air in the cylinders which assures complete combustion of the fuel, unless the engine is very poorly adjusted.

Initial cost of diesel engines is higher than gasoline engines of comparable displacement or horsepower. Several factors account for this. The fuel-injection system is much more costly than the fuel-induction system of a spark-ignition engine. Diesel engine construction is heavier and, therefore, more costly because higher peak pressures are encountered. However, the heavier construction repays at least a portion of its cost in long, trouble-free engine service.

Because ignition of the fuel in a diesel engine depends upon the temperature of the air compressed in the cylinders, starting at low ambient temperatures would be difficult without some starting aid, particularly in smaller engines. One manufacturer has estimated the temperature below which a starting aid is necessary at 45 F. One reason for this is that, if the air is cold enough, compression in the cylinder simply cannot raise the temperature of the air to the value required for ignition. Additionally much of the heat of compression is transferred to cold engine parts. However, starting aids have been developed to make starting possible and easier at low temperatures. These include devices for burning diesel oil to heat the intake air, ether injectors and glow plugs.

Unlike gasoline engines, diesel engines do not resolve themselves into distinct groups such as aircraft, marine and automotive with quite dif-

Fig. 35 — Eight-cylinder, V-type diesel engine has 603 cubic inch piston displacement and develops 182 bhp at 2800 rpm



ferent design characteristics. They are, all basically, general-purpose engines. That is to say, they are not completely designed for a specific application although the majority of manufacturers are prepared to add necessary equipment or modify the basic engine to fit it for specialized service, such as marine or automotive. Perhaps the only distinction which can be made is on the basis of weight. Although basic design and construction are similar, *Fig.* 32, engines exceeding 6000 pounds weight will ordinarily be found only in stationary, marine, railcar or locomotive service.

Output: Horsepowers of available diesel engines range from approximately four to 5000 and even higher. Speeds at which maximum horsepowers are developed range from below 600 to 3000 rpm. The great majority of diesel engines develop maximum horsepower at speeds of 1200 to 2200 rpm.

Maximum torque of these engines vary from 11 to well over 15,000 lb-ft. Speeds at which maximum torques are developed range from 600 to 2000 rpm, although very few diesels develop maximum torque at speeds exceeding 1500 rpm.

Size and Weight: Weight to power ratios vary from approximately 6 to 80 pounds per horsepower. More than 80 per cent of diesel engines have weight to power ratios of 15 to 45 pounds per horsepower. For engines of comparable design, construction and operating conditions, weight per horsepower is roughly proportional to cylinder bore.

Construction and Design: With the exception of less than half a dozen models produced by one manufacturer, *Fig.* 33, all U. S.-made diesel engines are watercooled. Number of cylinders may be 1, 2, 3, 4, 5, 6, 8, 10, 12, or 16. Cylinder arrangements may be in-line, *Fig.* 34, Vee, *Fig.* 35, or radial. Some of the very large engines use an opposed piston arrangement, *Fig.* 36. More than 50 per cent of the engines produced are 6-cylinder in-line types. All diesel engines of 6 cylinders or less are in-line types with only one or two exceptions. Engines having more than eight cylinders are usually V-types, while eight-cylinder engines may use either in-line or V cylinder arrangements.

Overhead valves are the rule in diesel engines. No diesels made use either L-head or F-head valve arrangements, which would be unsuitable for high compression.

Some two-cycle engines use no valves at all, such as loop-scavenged engines, *Fig.* 37, and opposed-piston engines, *Fig.* 36.

The scavenging system used with opposed-piston engines is known as a uniflow system because there is no change in the direction of exhaust gas flow during scavenging. Uniflow scavenging is also used on other than opposed

Fig. 36—Opposed-piston, two-cycle diesel engine uses no valves. Ports in cylinder walls when uncovered by pistons function as valves. Air from a scavenging blower enters at one set of ports and blows exhaust gases out the other set. Because movement of air and gases in cylinder does not reverse during scavenging, this is known as uniflow scavenging. Bore and stroke of the cylinder shown are 8⅛ and 10 inches respectively

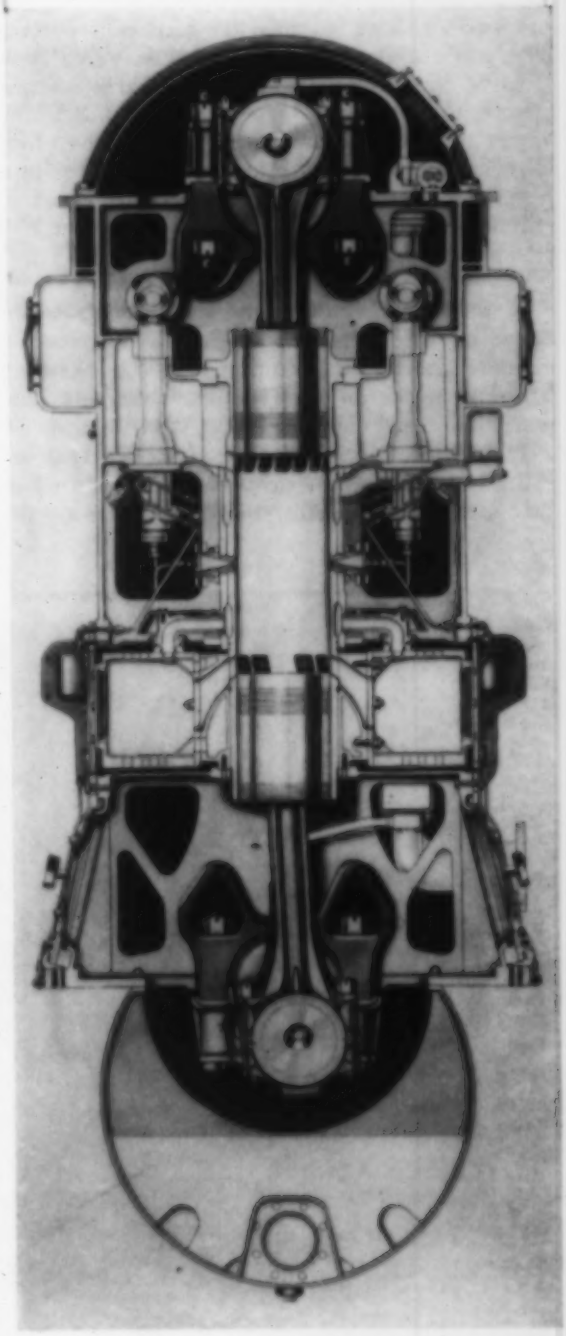


Table 1—Effect of Supercharging 4-Cycle Water-Cooled Diesel Engines

	—Unsupercharged—			—Supercharged—			Gain from supercharging	
Displ't. (in^3)	Weight (lb)	Hp	Weight (lb/hp)	Weight (lb)	Hp	Weight (lb/hp)	Hp increase (%)	Wt/hp decrease (%)
11880	42,300	875	49.5	43,700	1315	33.2	50	49
9572	33,200	625	53.0	34,800	1000	34.8	60	52
2505	9,800	388	25.2	10,500	516	20.3	36.5	18
743	2,680	200	13.4	2,975	275	10.8	38	24

piston, two-cycle engines, *Fig.* 38. Exhaust valves only are used in this particular type of engine; no intake valves are required. Certain engines use four valves per cylinder, two intake and two exhaust, to provide increased porting area while maintaining a favorable valve head to valve seat area which improves valve cooling.

Both dry and wet type cylinder liners are widely used in diesel engines. The cast-en-bloc cylinder, although used, is almost a rarity in a diesel engine. Details of these three types of cylinder construction were covered in Part I of this article.

Combustion Chambers and Injection Systems: Heart of the diesel engine is its combustion chamber and fuel injection system. At least six different types of combustion chambers and nearly as many injection systems are used in U. S. diesel engines. Purpose of all the systems is the injection of the proper amount of fuel at the correct time during the latter part of the compression stroke and then to properly burn it to obtain the maximum available power from the fuel. Although much could be said about the design and construction of injection systems and combustion chambers, it appears unnecessary to evaluate their relative merits. Each has stood the tests time and competition.

Starting Methods: Manual starting is used only on diesel engines having one or two cylinders and piston displacements less than 100 cubic inches. High compression ratios and engine size make the use of some type of power starting mandatory on larger diesels. Electric, pneumatic or hydraulic starting motors, and gasoline engines, are used, with one known exception. *Fig.* 39. Selection of a starting method is usually determined by the engine application.

Electric cranking is commonly used when the engine is used to drive a generator or when it is desirable to use an auxiliary battery charging generator and storage batteries for some purpose such as lighting. In an engine-generator application, the generator is usually constructed so that it can be motored to start the engine. When an auxiliary battery-charging generator is used, a starting motor, *Fig.* 40, is installed to crank the engine. Electric starting is also advantageous for applications where the engine is unattended and must start when some change in pressure, temperature or other condition occurs, since a switch which responds to the particular condition can initiate starting.

Disadvantages of electric starting are the fire hazard which may exist in certain applications and the energy loss of storage batteries when

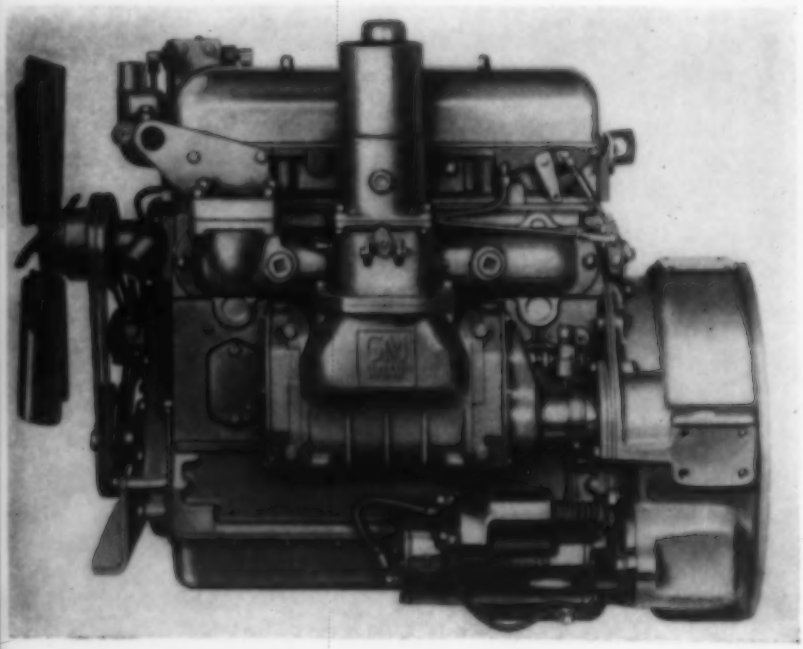
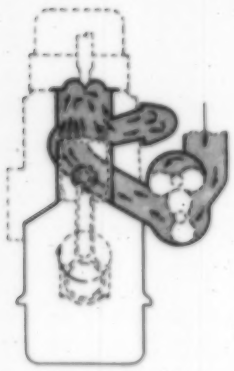


Fig. 37—In the loop scavenging system for a two-cycle diesel engine, scavenging air enters through ports in cylinder walls, moves to the top of the cylinder and then reverses direction to exit through ports on the side of the cylinder wall opposite the inlet ports. Four-cylinder engine using this system develops 76 bhp at 2500 rpm with piston displacement of 216.5 cubic inches



cold. Though more power is required to start the engine when cold because lubricating oil becomes more viscous at low temperatures, energy available from a storage battery decreases as its temperature is lowered. This can make cold starts extremely difficult.

Small gasoline engines, handcranked or battery started, offer certain advantages where cold starting is a problem. By connecting the cooling system of the starting engine into the cooling system of the diesel, heat of the gasoline engine cooling liquid can be used to warm diesel coolant. Hot exhaust gases of the gasoline engine may also be used to heat the diesel's intake air. Additionally, the small gasoline engine can crank for long periods while storage battery capacity limits the length of time an electric cranking motor can be used. Disadvantages of the gasoline engine are the starting of the gasoline engine itself and the necessity of having gasoline available as well as diesel fuel.

Compressed air starting motors are comparable in size and weight to electric starting motors. When used in applications where compressed air is already available from an external source, they offer considerable space and weight advantages over gasoline or electric starting. Engine-driven compressors may, of course, be used to refill air reservoirs for operation of the starting motor, if an external source is not available. However, sustained cranking capacity of such a system would not be as good as the electric starting system. Compressed air starting eliminates any fire hazard which might exist with either gasoline or electric starting. Some diesel engines are started by direct injection of compressed air, through special starting valves, into some or all of the main cylinders.

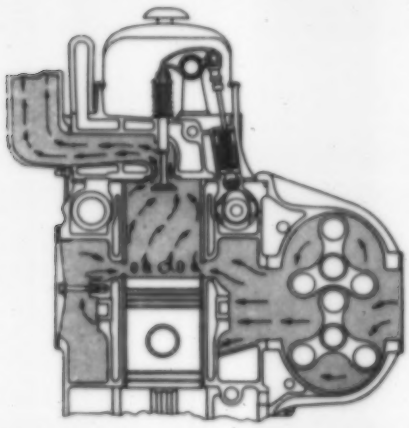
Hydraulic cranking systems offer freedom from fire hazards. Weight and size of the system are approximately the same as for the electric system. In addition to the cranking motor, the hydraulic system includes an accumulator, either a hand-operated or an engine-driven pump or both for charging the accumulator, and a control valve.

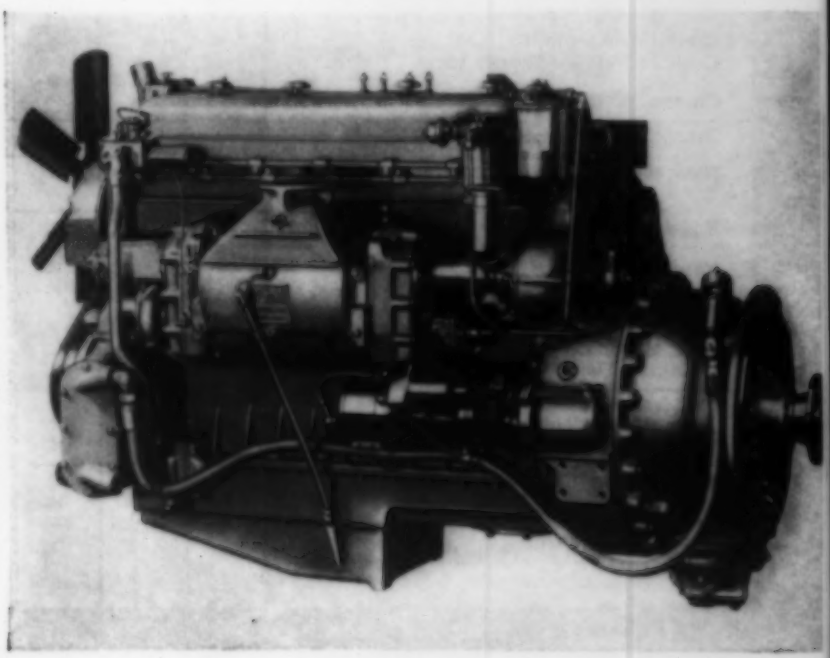
Pricewise, the pneumatic starter is definitely the most economical when used with an already existing source of compressed air. Comparative costs of the other systems vary both with engine size and manufacturer. System character-

Table 2—Accessories and Parts Which Should Be Accessible

Air cleaner	Oil drain plug
Carburetor	Oil filler cap
Connecting rod bearings	Oil filter
Controls	Oil level gage
Cylinder heads	Oil pan
Fan belt	Oil pressure relief valve
Fuel filter	Radiator drain cock
Fuel pump	Radiator filler cap
Generator	Starting motor
Hose connections	Thermostat
Ignition system	Timing gear or chain
Injection system	Timing marks
Main bearings	Valve tappets
Manifolds	Valves
	Water pump

Fig. 38—Uniflow scavenging system is used in this 6-cylinder, two-cycle diesel engine. Scavenging air enters through ports in the dry cylinder liners and exhausts through valves in the cylinder head. A roots-type blower provides scavenging air. Maximum bhp is 210 at 2100 rpm. Piston displacement is 425.6 cubic inches





istics rather than price is usually the deciding factor.

Supercharging: Although practically never used with general-purpose gasoline engines, superchargers are sometimes used on general-purpose diesel engines. When a decision as to whether or not to supercharge is made, the gain in output must be weighed against the cost, weight and complication of the supercharger. It has been found that the advantages of supercharging often outweigh the disadvantages on these engines.

Analysis of the increased horsepower and low-

Table 3 — CHARACTERISTICS OF U. S. MADE ENGINES

Manufacturer	Gasoline	Diesel	Air Cooled	Water Cooled	Cycle	No. Cyls.	Hp	Speed (rpm)	Purpose
Aerojet General Corp.	x			x	4	4	26.5	5400	General
Aircooled Motors Inc.	x		x		4	4–6	75–240	1950–3275	Aircraft
Allis-Chalmers Mfg. Co.	x			x	4	4	24.5–110	1050–1800	General
American Locomotive Co.		x		x	4	6–16	550–2400	600–1000	Locomotive
Atlas Supply Corp.		x		x	4	4–8	192–580	750–1225	General, Marine, Railcar
Baldwin-Lima-Hamilton Corp.		x		x	4	6–8	430–1750		Locomotive
		x		x	2	5–12	2350–5450		Stationary, Marine
Berry-Hill Corp., Hill Diesel Engine Div.		x		x	4	2–6	10–75	1500	Stationary, Marine
Bolinders Co., Inc.		x		x			6–1500		Marine
Brennan Motor Mfg. Co.	x			x	4	4–6	27–200		Marine, General
Briggs & Stratton Corp.	x		x		4	1	0.73–8.4	1800–3600	General
The Buda Co.	x			x	4	4–8	15.5–259	1000–3000	General, Marine
		x		x	4	2–8	9–516	1200–2800	General
Caterpillar Tractor Co.		x		x	4	4–12	54–500	1000–2000	General
Chicago Pneumatic Tool Co.	x	x		x			120–1750		
Chris-Craft Corp.	x			x	4	4–6	60–190		Marine
Chrysler Corp., Marine and Industrial Engine Div.	x			x	4	6–8	99–183	3600–4000	General
Climax Engine & Pump Mfg. Co.	x*			x	4	4–12	123–605	1200	General
Clinton Machine Co.	x		x		2	1	2.5		General
	x		x		4	1	0.7–9.0		General
Continental Motors Corp.	x		x		4	1	2–3		General
	x			x	4	4–6	14.2–275	1400–3600	General
	x		x		4	4–6	65–290		Aircraft
		x		x	4	4–8	39–225	1600–2400	General
Cooper-Bessemer Corp.		x		x	4	6–16	825–2200		Locomotive, Stationary
Cummins Engine Co. Inc.		x		x	4	4–12	100–600	1800–2200	General
Cushman Motor Works Inc.	x		x		4	1	3–5	3000	General
	x			x	4	1	3–5.4	850	General
Curtiss-Wright Corp.	x		x		4	7–18	800–3250	2400–2600	Aircraft
Detroit Diesel Engine Div., GMC		x		x	2	2–6	30–300	1800–3000	General
Electro-Motive Div., GMC		x		x	2	6–16	560–1900		Locomotive, Stationary
Fageol Products Co.	x*			x	4	6	180–210	2800	General
		x		x	4	6	162–184	2400	General
Fairbanks, Morse & Co.		x		x	4	6–10	2000–3500		Stationary
		x		x	2 or 4	4–12	300–2400		Marine, Locomotive, Stationary
Ford Motor Co., Industrial Engine Dept.	x			x	4	4–8	40–170	2000–4000	General
Gladden Products Corp.	x		x		4	1	4.3–9.5		General
Gray Marine Motor Co.	x			x	4	4–6	16–180	1800–4000	Marine
		x		x	4	4–6	30–140	1800–2400	Marine
Hallett Mfg. Co.		x	x		4	1–2	7.5–14		General
		x		x	4	1–4	8–20		General
Hall-Scott Motor Div., ACF-Brill Motors Co.	x*			x	4	6–12	157–630	2100–2800	General, Marine

ered weight to horsepower ratio obtained by supercharging four typical engines of different types, *Table* 1, indicates that the advantages of supercharging are less pronounced for smaller engines. As engine displacement and weight decrease, a point is eventually reached at which cost and weight of a supercharger would exceed either or both the cost and weight increase resulting from simply making the engine larger.

Gain in horsepower obtained by supercharging is actually a result of improved volumetric effi-

Manufacturer	Gasoline	Diesel	Air Cooled	Water Cooled	Cycle	No. Cyls.	Hp	Speed (rpm)	Purpose
Harnischfeger Corp.		x		x	2	2–6	30–255		General
Hercules Motors Corp.	x			x	4	2–6	10–236	2000–3200	General
		x		x	4	2–8	24–510	1800–3000	General
International Harvester Co.	x			x	4	4–6	17–214	1600–2500	General
		x		x	4	4–6	58–203	1400–1800	General
Jacobs Aircraft Engine Co.	x		x		4	4–7	150–300		Aircraft
	x			x	4	4–6	57–150		General
Kermath Mfg. Co.	x			x	4	1–12	5–580	2400–3600	Marine
		x		x	4	2–6	27–250	1800–2600	Marine
Kohler Co.	x*		x		4	1–2	3.6–17.0		General
Ingersoll-Rand Co.		x		x	4	6–8	203–353	1000	Stationary
	x†			x	4	4–12	200–1320		Stationary
The Lathrop Engine Co.	x			x	4	3–6	27–179	700–3200	Marine
The Lauson Co.	x		x		4	1	1–6.3		General
Le Roi Div., Westinghouse Airbrake Co.	x			x	4	1–12	14.5–645		General
Lycoming Div., Avco Mfg. Corp.	x		x		4	4–8	140–400		Aircraft
Minneapolis-Moline Co.	x			x	4	4–12	38–263		General
		x		x	4	4–6	46–95		General
Murphy Diesel Co.		x		x	4	4–6	105–240	1200–1400	General
National Supply Co.		x		x	4	4–6	192–675	750–1225	General, Marine, Railcar
Nordberg Mfg. Co.		x		x	4	1–3	10–45		General
The Oliver Corp.	x			x	4	4–6	27.8–65.8	1600–2000	General
		x		x	4	4–6	24.2–65.8	1600–2000	General
D. W. Onan & Sons Inc.	x		x		4	2	4.5–10	1200–3000	General
Packard Motor Car Co.		x		x	4	6–16	300–800		Marine, General
Palmer Engine Co.	x			x	4	1–6	6–165		Marine
Power Products Corp.	x		x		2	1–2	1.5–5		General
Pratt & Whitney Aircraft, Div. United Aircraft Corp.	x		x		4	14–28	1450–3500	2700–2800	Aircraft
R. H. Sheppard Co. Inc.		x		x	4	1–6	3.75–100	1800–2000	General
Sterling Engine Co.	x*			x	4	6–8	123–600		Stationary
		x		x	4	6–8	420–1000		Stationary
Universal Motor Co.	x			x	4	1–6	8–145	1200–3800	Marine
Waukesha Motor Co.	x			x	4	4–6	18–515	1100–3000	General
		x		x	4	4–6	45–570	1200–2800	General
West Bend Aluminum Co.	x		x		2	1	1.5–3.0	3600–4200	General
Willys Motors Inc.	x			x	4	4–6	63–118	3650–4200	General
Wisconsin Motor Corp.	x		x		4	1–4	4.6–36	2200–3600	General
Witte Engine Works, U. S. Steel Corp.	x			x	4		4–18		
		x		x	4		5–10		
Worthington Corp.				x	4	5–16	190–4500		Marine, Stationary
	x†	x§		x	4	5–16	150–5000	360–1000	Marine, Stationary
Zephyr Products Co.	x		x		4	1–8	3.5–36	3200	General

* Also for gas operation. † For natural gas or similar fuel. § Also for dual fuel operation.

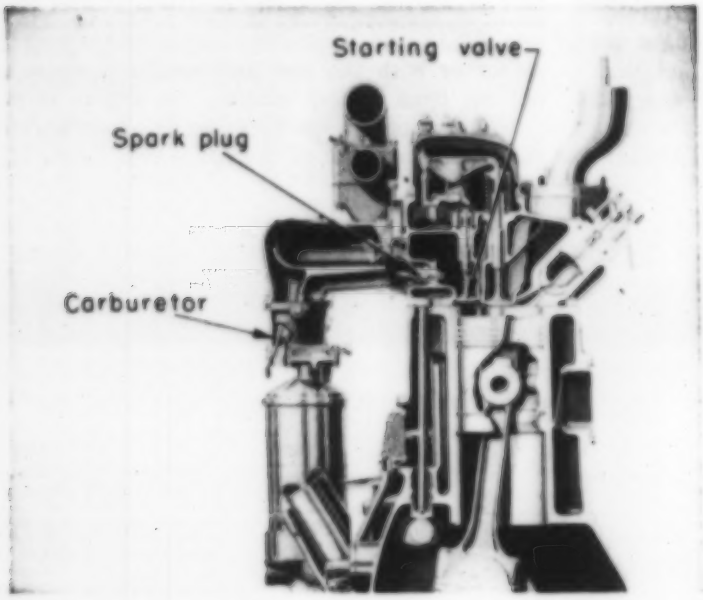


Fig. 39—An unusual starting method is used on this engine. Mechanical linkage opens the starting valve and stops operation of the fuel injection system. Opening the starting valve effectively increases combustion chamber size and reduces compression ratio. The carburetor and a complete ignition system permit starting and running as a gasoline engine. Operation of the lever controlling the starting valves then converts to diesel operation

ciency. The supercharging process is simply one in which an air pump or blower forces air into the cylinders at pressures higher than atmospheric. This makes possible the burning of an increased amount of fuel although cylinder volume remains the same. Roots type, *Fig.* 38, are centrifugal blowers are used. Roots blowers are usually mechanically driven by the engine. Centrifugal blowers may be driven either mechanically or by a turbine which is driven by the engine exhaust gases.

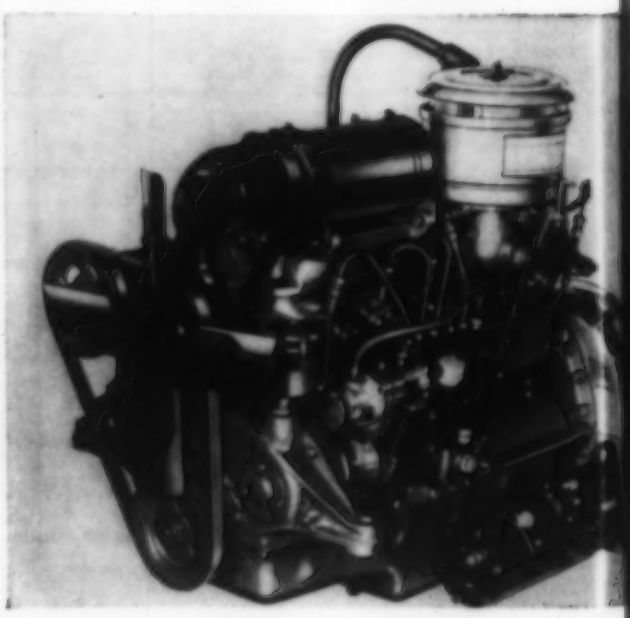
Selection Factors

When certain of the factors ordinarily affecting engine selection are paramount rather than being one of many to be given equal consideration, the problem of engine selection is greatly simplified. For example, if low weight is the primary consideration an air-cooled gasoline engine would be chosen, *Fig.* 41. In other cases the general engine type is dictated by a certain all-important requirement. Diesel engines are always used when fuel economy is the prime consideration, *Fig.* 42. On the other hand, low first cost makes the use of a gasoline engine mandatory.

Usually the problem of selection is not this simple. The considerations mentioned are only a few of those which must ordinarily be weighed before the problem can be resolved. Various factors which should be considered will be mentioned and discussed, not necessarily in the order of their importance, since this varies from case to case. Unless specifically stated, the following discussion applies to gasoline or diesel engines.

Horsepower: Certainly the first question to be asked when selecting an engine is: What is the required horsepower? This may be determined from the torque and speed requirements of the load. In the event that the engine is to

Fig. 40—An electric cranking motor and battery charging generator are installed on this automotive type diesel engine



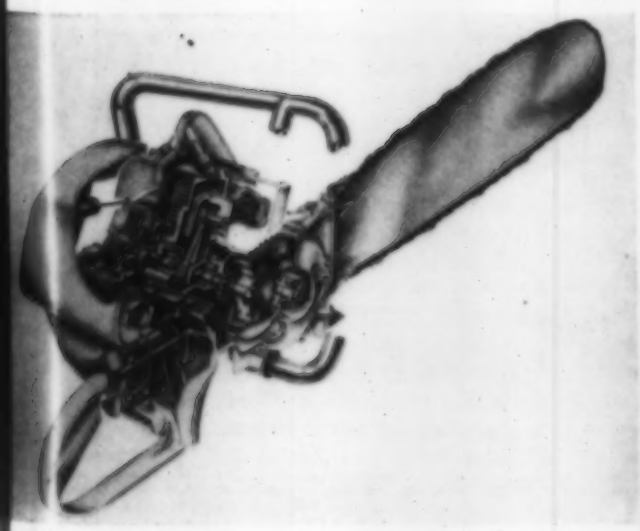
power a machine smaller or larger than a similar existing machine, power requirement might be determined on a proportional basis. Sometimes it may be necessary to obtain sample engines and determine the power required by experiment.

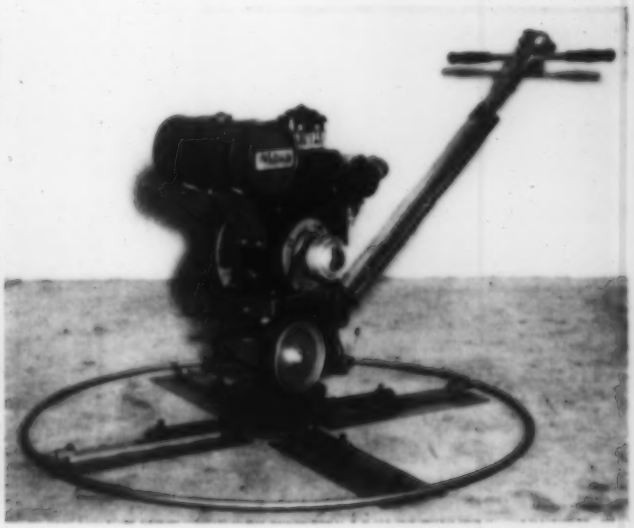
Another method for determining required horsepower occurs when it is desired to design or modify an existing product powered by an electric motor to offer purchasers the option of engine power. Here, horsepower requirement for the engine may be determined from the power of the electric motor. Most motors will develop 25 per cent more than rated power for one or two hours and may handle 50 per cent or greater overloads for shorter periods. An engine for the same service should develop from 75 to 100 per cent more power than an electric motor for this and other reasons to be discussed.

With speed and torque, or horsepower requirement of the load known, the significance of internal combustion engine horsepower ratings should be examined. Unless some other conditions are very definitely specified, horsepower quoted for an internal combustion engine is the maximum horsepower an engine in good condition will develop on a dynamometer test at an ambient temperature of 60 F and normal sea level barometric pressure of 29.92 inches of mercury. During this test, the engine is usually not driving certain accessory items such as cooling fan, water pump and a battery charging generator which might be a part of the final engine installation. Each of these items will absorb some of the engine output, thereby lowering actual available power.

Other conditions which reduce power output are high ambient temperatures, altitude and engine wear. A 10 F rise in ambient temperature reduces power output by one per cent because intake air is less dense and, therefore, contains less oxygen. If intake air is taken from engine enclosure, power losses of 5 to 10 per cent may result from heating of the intake air. For every inch reduction of barometric pressure or 1000 feet of altitude above sea level, output of gasoline engines decreases from 3 to 3.5 per cent, again because of lowered intake air density. Since diesel engines operate with an excess of air, power losses resulting from lowered barometric pressure or increased altitude are not usually considered until pressure drops more than 1.5 inches which is the equivalent of 1500 feet above sea level. From 1500 feet up, losses are approximately the same as for gasoline engines. If it can be established that an engine is to operate continually at high altitude or with high intake air temperature, carburetor or injection system can be adjusted to prevent wasting fuel which cannot be burned because of the lack of oxygen. However, there is no means other

Fig. 41—Low weight was one of the primary considerations in selecting the engines for the chain saw, left, and cement finishing machine, right. Both use air-cooled gasoline engines. The 4-cycle engine used on the Whiteman Mfg. Co. cement finisher develops 7 hp and weighs 83 pounds. Weight of the entire chain saw complete with 3½ hp two-cycle engine is 22 pounds. Ability of two-cycle gasoline engines to run in any position was another prime factor in the selection of the chain saw engine





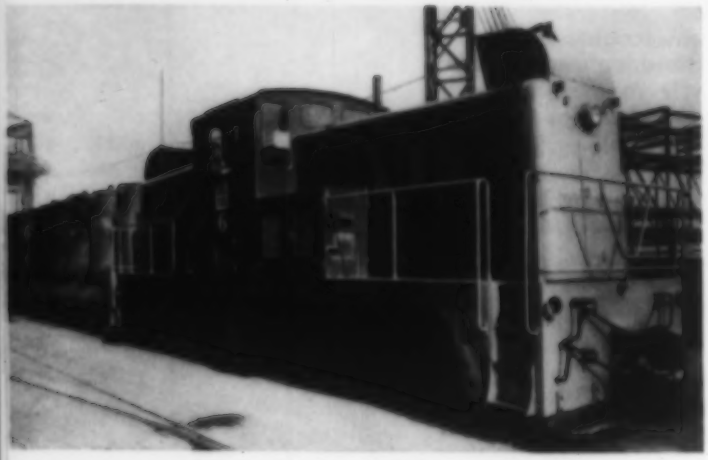


Fig. 42—Savings attendant upon the use of diesel oil as fuel make the use of diesel engines mandatory in pieces of equipment such as these. All are intended to operate fairly continuously over long periods of time at nearly full engine output. Weight of the diesel engines can be a benefit in applications like these. In the locomotives, increased weight improves tractive effort. Engine of the power shovel helps to counterbalance boom, bucket and load

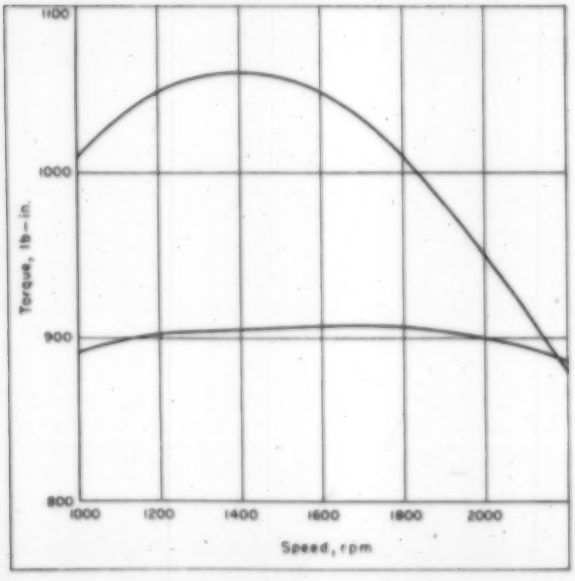
than supercharging to prevent the power loss.

Engine manufacturers recommend that their engines should not be operated continuously at maximum power. Certain of them also recommend that for continuous operation their engines should operate at speeds lower than those at which maximum horsepower is developed. Recommended power reduction for continuous operation is more than 40 per cent in some cases. A more nearly representative or average figure is 25 per cent. Even for intermittent or variable-load duty, it is generally accepted practice to choose an engine whose output is 125 per cent of the highest expected load to allow a margin of safety for the unexpected load.

Thus far the discussion has been in terms of horsepower, but the fact that horsepower is a product of engine torque, engine speed and a constant calls for an evaluation of load requirements on the basis of required torque and speed as well as horsepower. Ignoring mechanical and friction losses, an engine of a certain horsepower in conjunction with the proper gear set will provide that horsepower at any desired speed. However, the gear set adds its cost and weight to those of the engine. This suggests that speed and torque curves of engines in the required horsepower range should be closely examined by the designer. It also suggests that an engine with higher than necessary output might be a better choice than one having the required output, if the larger engine supplies the torque and rpm required at less cost than an engine of the required output plus a speed-changing device.

Torque curves also supply other information which may be of help in matching engine and

Fig. 43—Although both of the engines whose torque curves are shown here produce nearly equal horsepower at 2200 rpm, outputs differ greatly at other speeds



load. Some engines supply substantially constant torque over a wide range of speeds, others show a pronounced peak at a particular speed, *Fig.* 43. Load characteristics may often dictate choosing one of these rather than the other even though horsepower and speed are equal.

Cost: Actual engine prices are, of course, available from the manufacturers. Well worth mentioning is the fact that the purchaser of a product may be as interested in operating costs as in first cost. In many instances, operating costs may be of more importance than the difference in price of competing products. Since operating costs include repairs and lost productive time as well as the fuel and oil consumed during engine operation, these things must be considered, if an acceptable product is to be designed. Wide availability of service parts and personnel for a particular make of engine is a definite point in its favor. Purchasers have been known to favor an admittedly inferior machine because of the knowledge that repair parts were more readily available, when necessary.

Engine life is usually longer for the larger, heavier engine when power output is equal. However, there are many other ways in which life and reliability can be improved. Many of these such as special valve and valve seat materials and chrome-plated piston rings have been mentioned. Perhaps as good an indication as any of engine life is given by the warranty.

Engine Installation

Mounting: Perhaps the most important step in designing an engine installation is the actual mounting of the engine. Even the most smooth-running internal combustion engine will vibrate. This must be taken into consideration. If the engine is rigidly bolted to a structure whose natural vibration frequency is in the range of speed over which the engine will operate, resonance may cause damaging vibration of the engine and structure. Redesign of the engine supports is sometimes not too difficult and may eliminate this condition if it exists.

In some instances rubber vibration damping mounts may be necessary to limit vibration or to insulate the supporting structure from engine vibration. Since those mounts vary in design with the weight of the engine to be mounted and the vibration frequency of the engine, care must be used in their selection. The wrong mount may do more harm than good. Manufacturers of these mountings are the best source of information on their selection.

Air Flow: Regardless of the fuel used, an engine consumes many more pounds of air than of fuel during the combustion process. Therefore, the designer must locate the engine air intake so that the supply of intake air will not be restricted. Additionally, the intake air should be as cool and clean as possible. For these reasons, engine air cleaners should always be used and properly located. Good or proper location of an air cleaner varies with the application. Examples of this are (1) placing the air cleaner outside the engine compartment where the air is cooler when the engine is in an enclosure and (2) locating the air cleaner as high as possible for dusty applications.

Usually engines will also require air for cooling. Whether air or water-cooled, the heat sink is usually atmospheric air. Marine engines using sea, lake, or river water are exceptions.

Accessibility: In addition to the repairs which may become necessary, certain periodic checks, servicing operations and adjustments are required by engines. Accessibility of various parts of the engine and accessory items can be a deciding factor in the purchase of a piece of equipment. A check list of the parts of the engine assembly which should be readily accessible, *Table* 2, may serve as a guide in determining how well this portion of the installation problem has been solved. However, a mock-up or model may be the best means of solution.

Summary

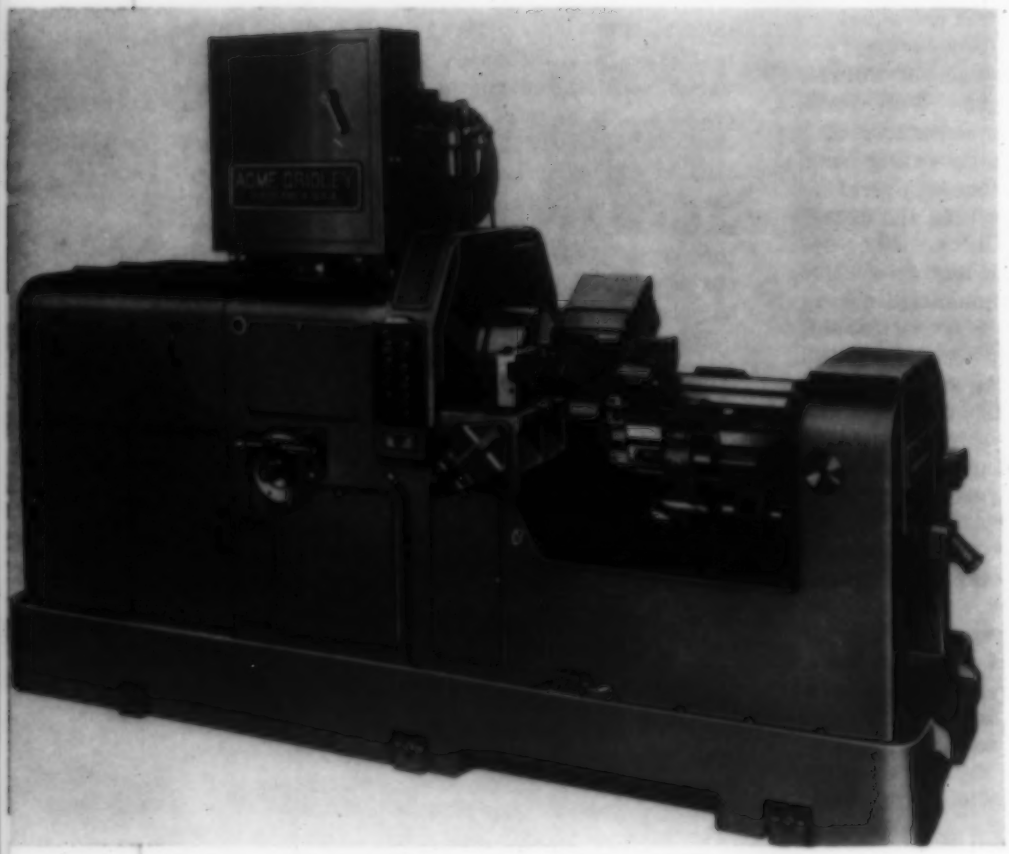
A summary of the more important characteristics of the products of many U. S. engine manufacturers, *Table* 3, may serve as a preliminary guide in engine selection. Although this table is as complete as possible, it should be understood that it does not necessarily include every manufacturer producing engines for sale.

ACKNOWLEDGEMENT

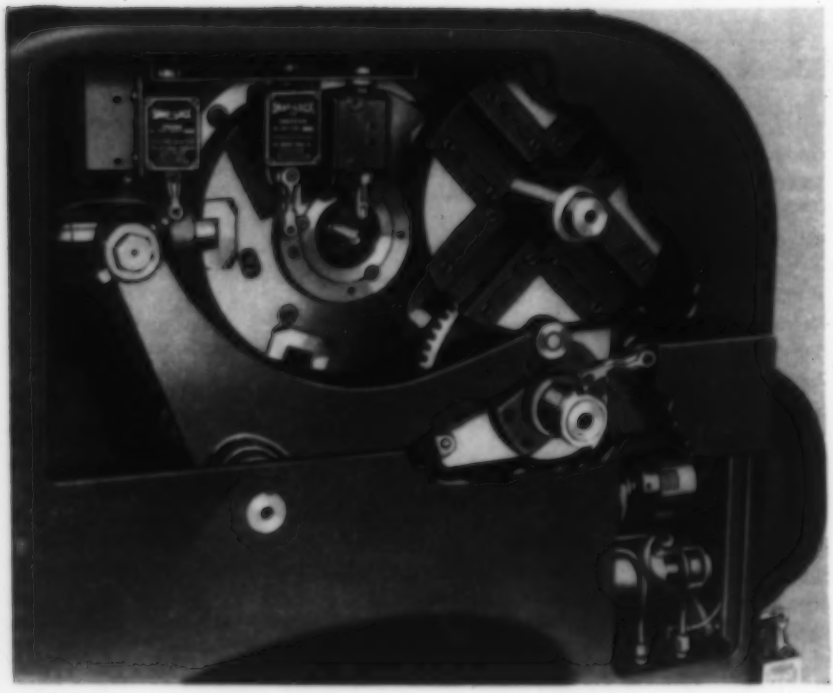
MACHINE DESIGN acknowledges with appreciation the co-operation of these companies in the preparation of the concluding part of this article in addition to those listed in Part 1.

American Locomotive Co. Schenectady 5, N. Y.
Baldwin-Lima-Hamilton Corp. (Fig. 42) Philadelphia 42, Pa.
Caterpillar Tractor Co. (Figs. 34, 42) Peoria, Ill.
Continental Motors Corp. (Fig. 35) Muskegon, Mich.
Detroit Diesel Engine Div., General Motors Corp. (Figs. 37, 38) Detroit 28, Mich.
Electro-Motive Div., General Motors Corp. (Fig. 42) La Grange, Ill.
Fairbanks, Morse & Co. (Figs. 32, 36) Chicago 5, Ill.
Gladden Products Corp. (Fig. 41) Glendale 4, Calif.
Hallet Mfg. Co. (Figs. 31, 33) Inglewood, Calif.
Hercules Motors Corp. (Fig. 40) Canton 2, Ohio
Homelite Corp. (Fig. 41) Port Chester, N. Y.
International Harvester Co. (Fig. 39) Chicago 1, Ill.
West Bend Aluminum Co. West Bend, Wis.
Worthington Corp. Harrison, N. J.

Chucker Has Independent Turret Cross Slides

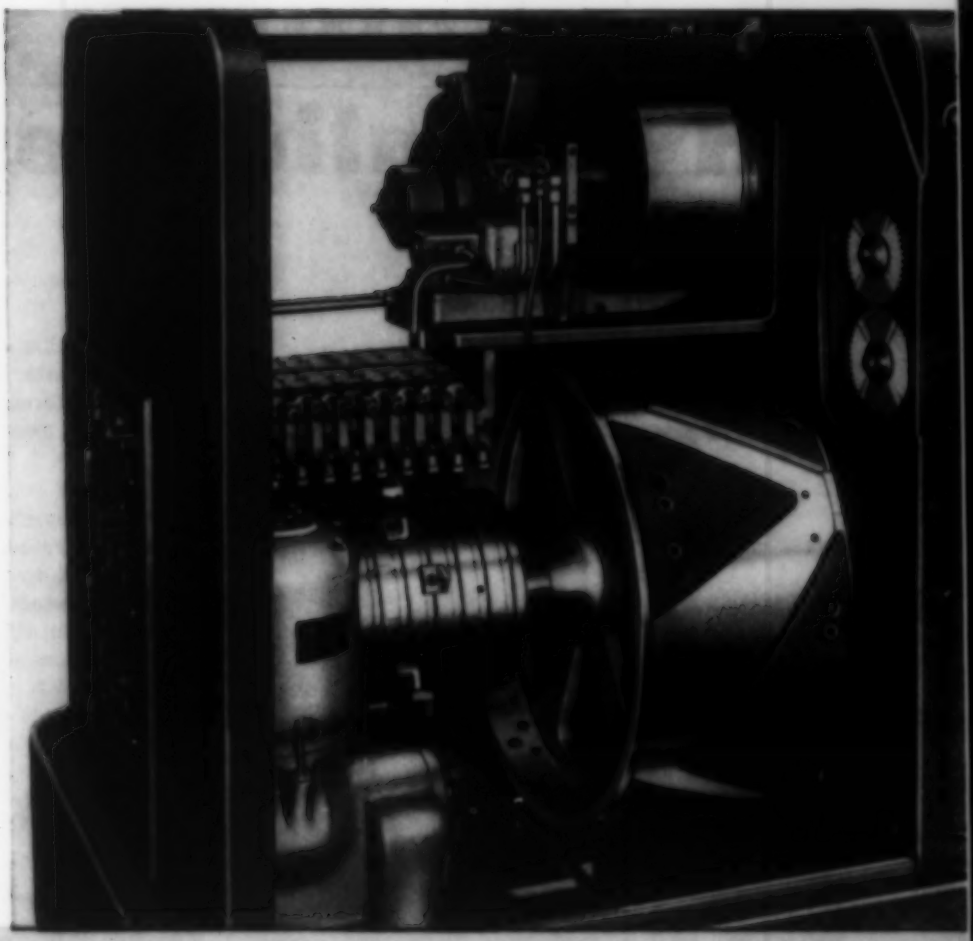


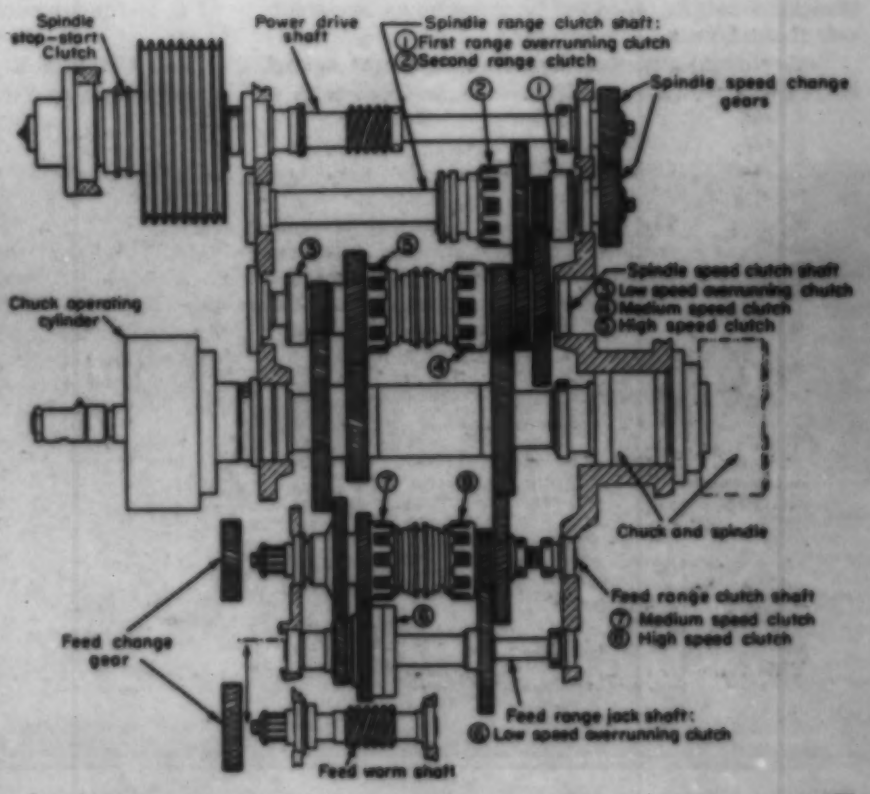
A RECENTLY introduced single-spindle chucking machine has completely automatic and independent operations of five tool slides on a turret and two cross slides. Heavy, rigid construction, and provision for using motors up to 40 hp, make high speeds and feeds possible when using carbide and high-speed tools. The tooling zone is open on sides and top. This is said to greatly facilitate tool changing and make possible the use of automatic loading equipment. The 12-inch chucking capacity machine has been christened Acme-Gridley Model MC by its manufacturers, the National Acme Co.



Turret index is controlled by a Geneva movement and performed by a separate motor, disk clutch and brake combination. Entirely independent of the cross slides, the indexing mechanism may be adjusted to index one or more positions while heavy forming cuts are continued by a cross slide. Safety limit switches prevent turret indexing until the turret toolslide is completely retracted.

Easily adjustable cam dogs on the main drum shaft and cam-operated switches automatically change speed and feed ranges as required for different cuts. Two clutch shafts which drive the work spindle provide two ranges of three speeds or a total of six speeds. Overrunning or roll clutches engage automatically when other clutches on a shaft are disengaged. Other clutches are engaged or disengaged by air cylinders actuated by solenoid valves. A similar system provides three speeds of the feed worm shaft. Change gears may be used for both feeds and speeds to give a selection of speed ranges.





How Rotation Affects Hydraulic Pressures

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and
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FLUID forces from rotation of hydraulic devices can become significant, especially at high speeds and large diameters. Machine components such as fluid couplings, axial displacement pumps and motors, centrifugal pumps, torque converters and transmission clutch cylinders, *Fig.* 1, are subject to forces caused by the spinning fluids contained within an enclosure.

This article will discuss the more important components and formulas will be derived for finding pressures and forces. It is felt that the discussion will be more useful and more easily understood if based on fundamental principles. These principles can be extended to cover many cases not contained herein.

Referring to *Fig.* 2, a container of height h, and length and width each equal to b, is filled with a liquid. If this column of liquid is divided into k small elements of volume each of height Δh, the downward force of each of the elements, ΔF, is equal to the mass of the cube times its acceleration:

$$\Delta F = mb^2(\Delta h)g$$

where the symbols have meanings defined in the *Nomenclature* and *Fig.* 2. The force transmitted, for example, by element 3 to element 4 is the sum of the forces above it plus its own force. Similarly, the force on the bottom of the container is the algebraic sum of the forces of the k cubes above it:

$$F = \sum_{n=0}^{n=k} \Delta F = mb^2 g \sum_{0}^{h} \Delta h \quad \ldots\ldots (1)$$

and the unit pressure at the bottom of the vessel is

$$p = \frac{F}{b^2} = mg \sum_{0}^{h} \Delta h = mgh \quad \ldots\ldots (2)$$

Equation 2 is simply the familiar formula for hydrostatic fluid pressure. But the method of arriving at it is fundamental to the following analysis.

Full Cylinder Rotating About Its Axis: The cylinder shown in *Fig.* 3 rotates at a uniform angular

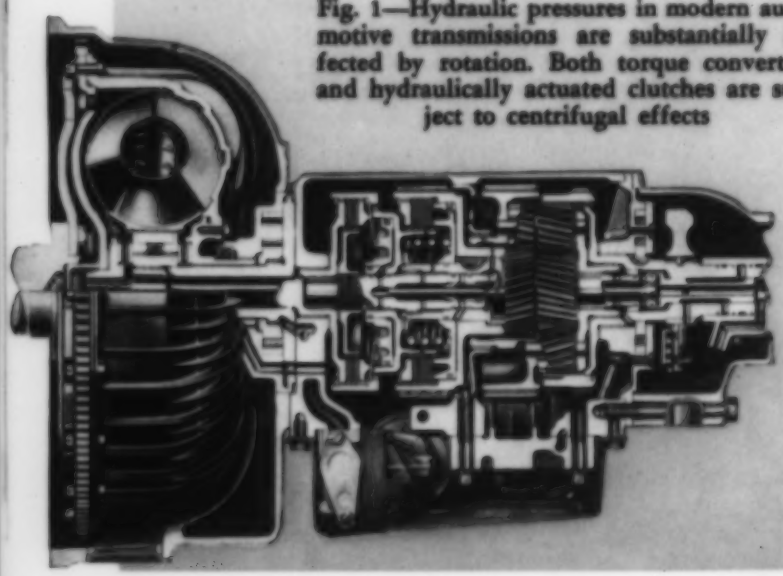


Fig. 1—Hydraulic pressures in modern automotive transmissions are substantially affected by rotation. Both torque converters and hydraulically actuated clutches are subject to centrifugal effects

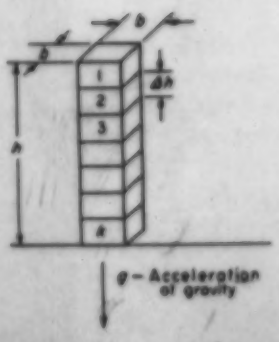


Fig. 2—Acceleration force, due to gravity, on a static column of fluid is equal at all points

Centrifugal action on hydraulic fluids in rotating parts adds appreciably to the system pressures. This article shows how to calculate these pressures, and the resulting forces, for the more usual types of hydraulic devices

velocity, ω radians per second, about its axis. Consider a thin radial column of fluid, divided into n increments each of height Δr, and length and width b. Each element is subject to centrifugal force,

$$\Delta F_c = mb^2(\Delta r)a$$

where a is the centrifugal component of acceleration $= \omega^2 r$. Notice that this expression is basically the same as the one given for a stationary column of fluid. The difference lies in the fact that acceleration due to gravity is, practically speaking, a constant, whereas a varies with radius. As in the foregoing example, the force exerted on the face formed by the sides of the column of element 4 is equal to the sum of the forces of the 4 elements counting from the center outward. Thus force on the Qth element may be stated

$$F_c = \sum_{n=0}^{n=Q} \Delta F_c = mb^2 \sum_0^r a\Delta r$$

and the unit pressure is

$$p = \frac{F_c}{b^2} = m \sum_0^r a\Delta r$$

Since $a = \omega^2 r$,

$$p = m\ \omega^2 \sum_0^r r\Delta r$$

As the increment Δr approaches zero in the foregoing expression,

$$p = m\,\omega^2 \int_0^r r dr \qquad (3)$$

which becomes, on integration

$$p = \frac{m\,\omega^2}{2} r^2 \qquad (4)$$

In practical units

$$p = \frac{W}{2g} \frac{4\pi^2 N^2}{3600} r^2$$

$$p = 1.419 \times 10^{-6} W N^2 r^2 \qquad (5)$$

Equation 5 gives pressure in pounds per square inch at any radius within the cylinder. This pressure not only acts outward but also acts in all directions. It would act against the end of the cylinder and against the end of the piston of the cylinder shown in *Fig.* 4. For a given fluid rotated at a given speed the pressure is a function of the radius only and is independent of the length of the cylinder or the volume contained therein.

Referring again to *Fig.* 4, an expression for

Fig. 3 — Acceleration force on a rotating column of fluid increases with the radius

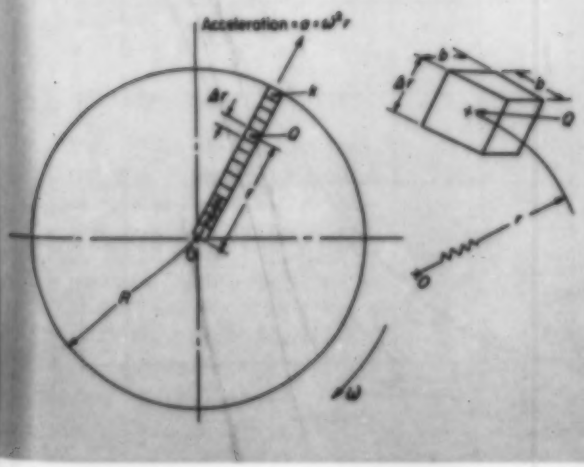
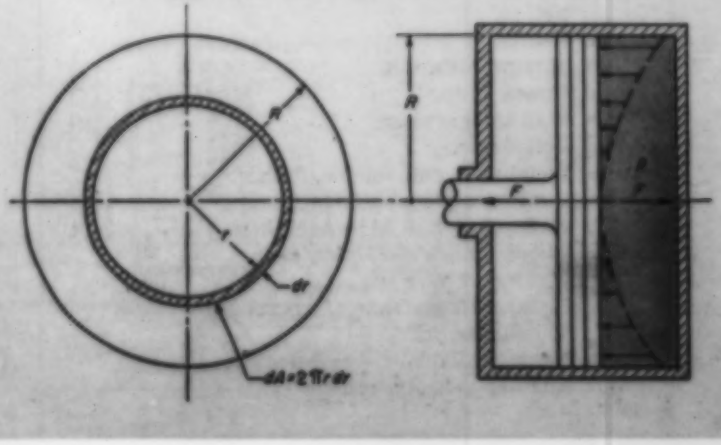


Fig. 4—Pressure developed by rotation alone can cause a force over 800 lb on the piston of a 6-inch cylinder revolving at 4000 rpm about its own axis. See Equations 5 and 7



force may be derived. Since pressure is a function of the radius, for an annular element of area as shown the element of force is pressure times area, or $dF_c = pdA$, where $dA = 2\pi r dr$ and p is given by Equation 4. Thus

$$dF_c = m\omega^2 \pi r^3 dr$$

Summing all the elements of force from $r = 0$ to $r = R$

$$F_c = \pi m \omega^2 \int_0^R r^3 dr = \frac{\pi m \omega^2 R^4}{4} \quad (6)$$

In practical units

$$F_c = 2.229 \times 10^{-5} W N^2 R^4 \quad (7)$$

As an example, a cylinder having a bore of 6 inches and rotating at 4000 rpm is filled with oil of specific gravity 0.8. Since the units of W in Equation 6 are pounds per square inch, specific gravity must first be converted to these units. The weight of water is 0.0361 lb per cu inch, therefore W for the oil equals 0.8 times that value,

Nomenclature

- A; dA = Area; element of area, in.^{2}
- a = Centrifugal component of acceleration, in.-sec^{-2}
- F = Force, total, lb
- F_c = Force, centrifugal, lb
- F_a = Force due to applied or charging pressure, lb
- F_d = Force on diaphragm portion of piston, lb
- F_p = Force on center plates of diaphragm piston, lb
- g = Acceleration of gravity, in.-sec^{-2}
- k = Ratio R_1/R_o
- L = Stroke, in.
- dl = Element of arc, in.
- m = Mass per unit volume, lb-sec^2-in.$^{-4}$
- N = Speed of rotation, rpm
- p, p_c = Pressure, centrifugal, lb-in.$^{-2}$
- p_a = Pressure, applied, lb-in.$^{-2}$
- r = Radius, in.
- r_o = Radius at which pressure originates, in.
- r_i = Inside radius of piston, in.
- R = Outside radius of piston, in.
- R_o = Outside radius of diaphragm, in.
- R_i = Radius of center plates in diaphragm piston, in.
- R_s = Radius of solid piston—equivalent of diaphragm piston, in.
- s = Stress, lb-in.$^{-2}$
- t = Wall thickness, in.
- V = Volume, in.^{3}
- W = Weight per unit volume, lb-in.$^{-3}$
- x = Dimensionless modifying factor, $(1/5)(1 + k + k^2 + k^3 + k^4)$
- y = Dimensionless modifying factor, $(1/3)(1 + k + k^2)$
- ρ = Distance from axis of rotation to center of cylinder, in.
- θ = Angle, radians
- ω = Angular velocity, rad-sec^{-1}

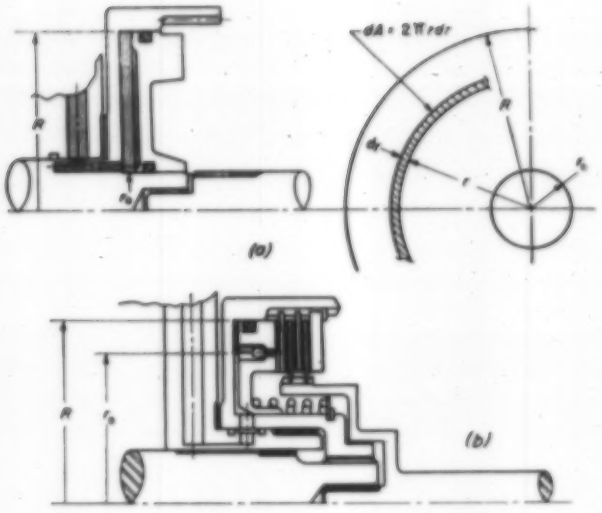
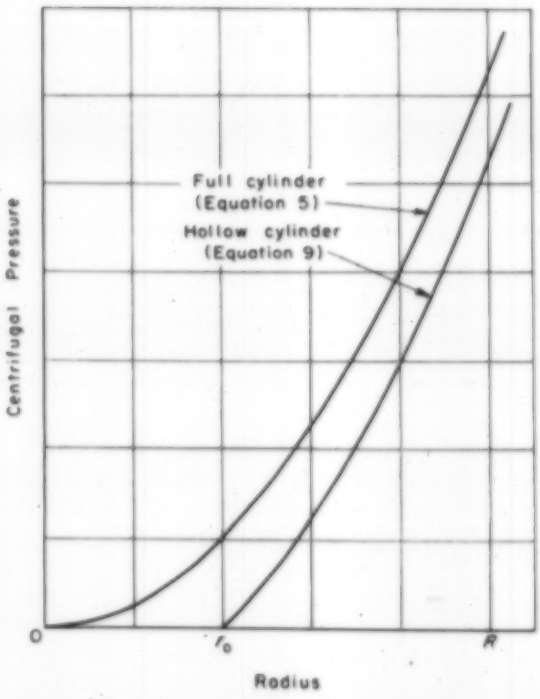


Fig. 5—Above—These automatic-transmission clutches are typical examples of hollow rotating hydraulic cylinders. Centrifugal pressure in design *a*, after release of actuating pressure, requires provision of a heavy disengaging spring. Design *b* spills all oil within radius r_o, after release of actuating pressure, cuts down disengaging force requirements. See Equations 9 and 11

Fig. 6—Below—Centrifugal pressure curves for full and hollow cylinders have constant difference beyond r_o. If $r_o = 0.4R$ as in this figure, total force on the hollow cylinder is 30 per cent less than on the full cylinder



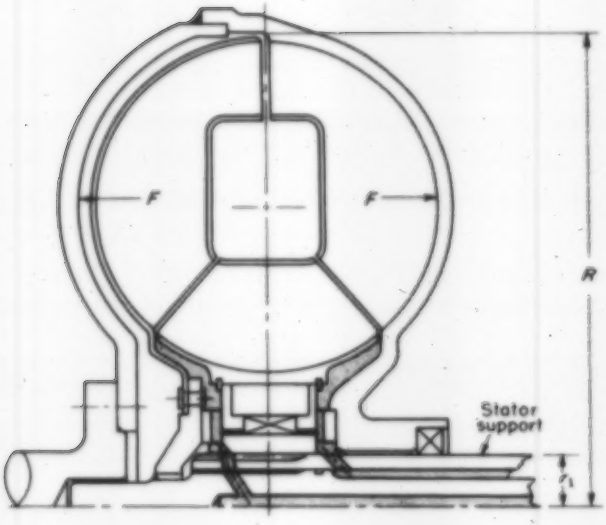
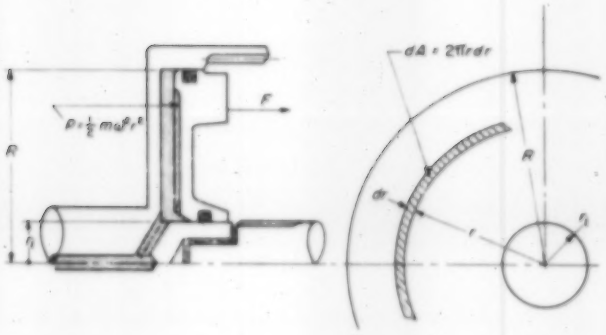


Fig. 7—Above—Hydraulic centrifugal pressure force F tending to separate a 12.8-inch diameter torque converter turning at 4400 rpm is almost 10 tons. Charging pressure of 50 psi adds another 3 tons

Fig. 8—Below—In this type of hollow cylinder, centrifugal pressure originates at center of rotation. Pressure variation therefore follows the "full cylinder" curve of *Fig.* 6, although total force is only that acting on the annular area between r_i and R. See Equations 5 and 13



or 0.0289. Substituting in Equation 7, $F_c = 2.229 \times 1010^{-5}(0.0289)(4000)^2(3)^4 = 832$ lb force against either end of the cylinder. To this force must be added any force due to applied pressure, F_a. This force will, of course, equal applied pressure times area, and $F = F_c + F_a$.

Hollow Cylinders: The first type of hollow cylinder to be discussed is illustrated by two examples in *Figs.* 5*a* and *b*. Both cylinders have the same type of pressure and force relationship in that when line pressure is cut off the point of pressure origin, r_o, is also the point where force against the piston begins. The arrangement shown in *Fig.* 5*b* is similar to rotating multiple-disk clutches used in several makes of automotive automatic transmissions. A ball relief valve unseats when line pressure is cut off and thereby spills all oil within radius r_o. This permits the clutch to disengage even though the return spring is lighter by far than the spring required in *Fig.* 5*a*. However, even with the relief valve there is still a small annulus of oil from r_o to R which must be accounted for in the return spring if clutch drag is to be prevented.

In these cylinders the inside portion of the cylinder from r_o to the center contributes neither force nor pressure, the pressure being zero at r_o and reaching a maximum at R. To obtain pressure at any point r within the cylinder Equation 3 can be used with the appropriate limits of integration, namely, r_o to r which represents any radius at which the pressure is to be determined:

$$p = m\omega^2 \int_{r_o}^{r} r\,dr = \frac{m\omega^2}{2}(r^2 - r_o^2) \qquad (8)$$

which, upon substitution of practical units, becomes

$$p = 1.419 \times 10^{-5}\, WN^2 (r^2 - r_o^2) \qquad (9)$$

Relationship between pressure and radius in a full cylinder and a hollow, or partly filled, cylinder is shown graphically in *Fig.* 6. The difference in pressure is constant from r_o to R.

For force on the piston, $dF_c = p\,dA$, where

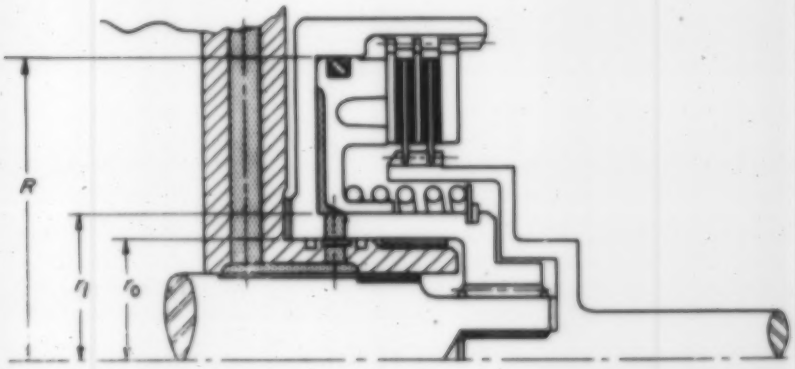


Fig. 9—In this design, centrifugal pressure originates at r_o and follows the "hollow cylinder" curve of *Fig.* 6. Total force is caused by pressure acting between r_i and R. See Equations 9 and 15 for proper formulas

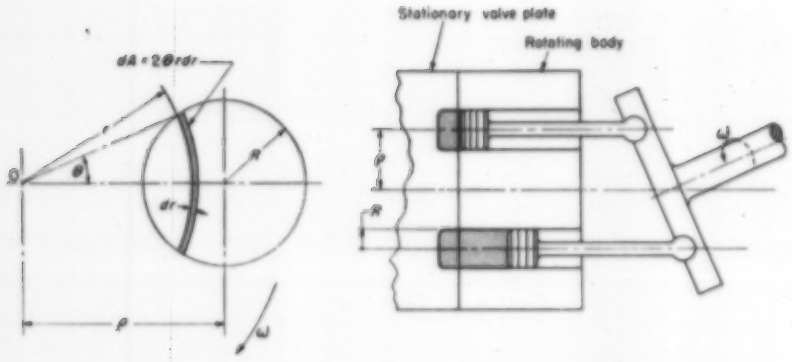


Fig. 10—In hydraulic motor or pump with rotating cylinder body and fixed valve plate, centrifugal pressure originates at the inner side of the bore. See Equations 9 and 17

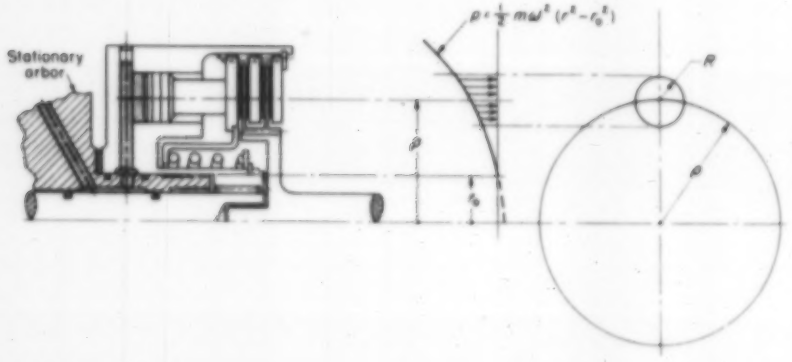


Fig. 11—Centrifugal pressure originating at axis of rotation causes higher piston forces than in design of *Fig.* 10. See Equations 5 and 18 for formulas

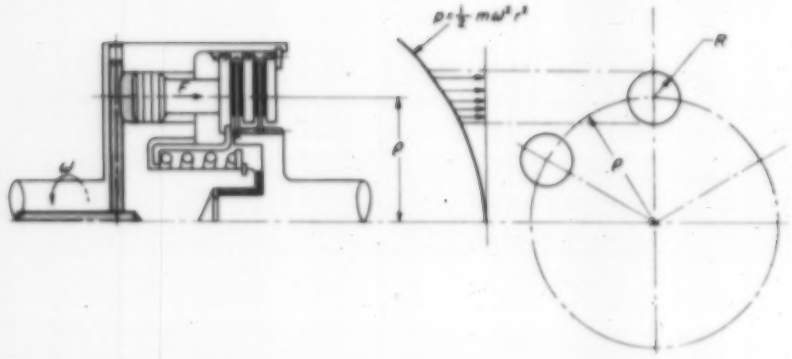


Fig. 12—Centrifugal pressure originates at stationary arbor, causes higher piston forces than in *Fig.* 10, but less than in *Fig.* 11. See Equations 9 and 21

dA is given by $2\pi r dr$, *Fig.* 5*a*, and p is found from Equation 8. Thus, $dF_c = \pi m\omega^2(r^2 - r_o^2)rdr$, and the total force is found by integration between the limits r_o and R:

$$F_c = \pi m\omega^2 \int_{r_o}^{R} r(r^2 - r_o^2)\, dr$$

$$F_c = \frac{\pi m\omega^2}{4} (R^2 - r_o^2)^2 \qquad (10)$$

In practical units

$$F_c = 2.229 \times 10^{-5} WN^2 (R^2 - r_o^2)^2 \qquad (11)$$

Equation 11 gives centrifugal force in a rotating hydraulic device in which pressure originates at the same radius that force does. For example, in the hydraulic torque converter shown in *Fig.* 7 the inlet and outlet oil holes are located in a nonrotating stator support. Thus, the radius of the support would be r_o, equal to 1.3 inch, R = 6.4 inches, N = 4400 rpm and the converter is charged with oil having a specific gravity of 0.8 at 50 psi.

Total force, F, is the sum of the centrifugal force F_c and the force due to charging pressure F_a. As in the previous example, W equals 0.0289. Centrifugal force is found by substituting in equation 11: $F_c = 2.229 \times 10^{-5}(0.0289)(4400)^2(6.4^2 - 1.3^2)^2 = 19{,}225$ lb. Force due to charging pressure equals pressure times area: $F_a = (50)(6.4^2 - 1.3^2)\pi = 6169$ lb. Then, total force $F = F_c + F_a = 25{,}394$ lb.

The second type of hollow cylinder to be considered has an oil passage to the cylinder which originates at the center of rotation as shown in *Fig.* 8. Since pressure originates at the center, Equation 4 should be used. In finding force on the piston, note that the pressure acts on the piston from r_i to R which will be the limits of integration. Then

$dF_c = p\,dA$, where $dA = 2\pi r dr$ and $p = \frac{1}{2}m\omega^2 r^2$ (Equation 4). Thus

$$dF_c = \pi m\omega^2 r^3 dr$$

$$F_c = \pi m\omega^2 \int_{r_i}^{R} r^3 dr$$

$$F_c = \frac{\pi m\omega^2}{4}\,(R^4 - r_i^4) \qquad (12)$$

In practical units,

$$F_c = 2.229 \times 10^{-5}\,WN^2\,(R^4 - r_i^4) \qquad (13)$$

The third type of hollow cylinder, shown in *Fig.* 9, has an oil passage connecting to a stationary arbor. This cylinder is the same as the one shown in *Fig.* 5*b* except that the ball check relief valve is not used. Here the pressure at any radius r originates at r_o where it is zero and, of course, becomes maximum at radius R. Therefore, this case is identical with the first type of hollow cylinder as far as pressure is concerned, and Equation 8 again applies. To find force, integrate from r_i to R. Since $dF_c = p\,dA$, where $dA = 2\pi r dr$ and $p = \frac{1}{2}m\omega^2\,(r^2 - r_o^2)$ from Equation 8,

$$dF_c = \pi m\omega^2 r\,(r^2 - r_o^2)\,dr$$

$$F_c = \pi m\omega^2 \int_{r_i}^{R} r\,(r^2 - r_o^2)\,dr$$

$$F_c = \frac{\pi m\omega^2}{4}\,[R^4 - 2r_o^2\,(R^2 + r_i^2) - r_i^4] \qquad (14)$$

In practical units

$$F_c = 2.229 \times 10^{-5}\,WN^2\,[R^4 - 2r_o(R^2 + r_i^2) - r_i^4] \qquad (15)$$

Off-center Cylinders: Some devices, instead of a single annular piston, have a group of small pistons located at a distance from the center of rotation. The first type to be dealt with is shown in *Fig.* 10. This arrangement comprises a stationary valve plate and a rotating cylinder barrel, as in axial displacement pumps and motors. Since the valve plate is stationary, pressure originates at the inner side of the cylinder bore. As before, $dF_c = p\,dA$, where $p = \frac{1}{2}m\omega^2\,(r^2 - r_o^2)$, from Equation 8. But $r_o = \rho - R$, therefore,

$$p = \frac{m\omega^2}{2}\,[r^2 - (\rho - R)^2]$$

Also $dA = 2\theta r dr$, and from the cosine law

$$\cos\theta = \frac{r^2 + \rho^2 - R^2}{2\rho r}$$

$$\theta = \cos^{-1}\frac{r^2 + \rho^2 - R^2}{2\rho r}$$

Combining the expressions for p, dA, and θ,

$$dF_c = m\omega^2 r\,[r^2 - (\rho - R)^2]\cos^{-1}\frac{r^2 + \rho^2 - R^2}{2\rho r}\,dr$$

Summing the elements of force from $\rho - R$ to $\rho + R$,

$$F_c = m\omega^2 \int_{\rho-R}^{\rho+R} r[r^2 - (\rho - R)^2]\cos^{-1}\frac{r^2 + \rho^2 - R^2}{2\rho r}\,dr$$

which, upon performing the indicated integration, yields this formula for calculating force on each piston:

$$F_c = \frac{\pi m\omega^2 R^3}{4}\,(4\rho - R) \qquad (16)$$

In practical units

$$F_c = 2.229 \times 10^{-5}\,WN^2R^3\,(4\rho - R) \qquad (17)$$

The second type of off-center cylinder, shown in *Fig.* 11, has pressure originating at the center of rotation. This case is similar to the foregoing except that the pressure originating at center provides a greater pressure against the pistons. Again, $dF_c = p\,dA$, where dA is the same as in the preceeding case and $p = \frac{1}{2}m\omega^2\,r^2$, from Equation 4. The complete expressions for element of force and total force become

$$dF_c = m\omega^2 r^3\cos^{-1}\frac{r^2 + \rho^2 - R^2}{2\rho r}\,dr$$

$$F_c = m\omega^2 \int_{\rho-R}^{\rho+R} r^3\cos^{-1}\frac{r^2 + \rho^2 - R^2}{2\rho r}\,dr$$

$$F_c = \frac{\pi m\omega^2 R^2}{4}\,(2\rho^2 + R^2) \qquad (18)$$

$$F_c = 2.229 \times 10^{-5}\,WN^2R^2\,(2\rho^2 + R^2) \qquad (19)$$

In the third type of off-center cylinder, *Fig.* 12, the pressure originates from a nonrotating arbor. Clutches of this type found use at one time in certain automatic transmissions. The only difference between this case and the two previous examples lies in the expression for pressure, which is $p = \frac{1}{2}m\omega^2\,(r^2 - r_o^2)$. Since dA and θ do not change,

$$dF_c = m\omega^2 r\,(r^2 - r_o^2)\cos^{-1}\frac{r^2 + \rho^2 - R^2}{2\rho r}\,dr$$

$$F_c = m\omega^2 \int_{\rho-R}^{\rho+R} r\,(r^2 - r_o^2)\cos^{-1}\frac{r^2 + \rho^2 - R^2}{2\rho r}\,dr$$

$$F_c = \frac{\pi m\omega^2 R^2}{4}\,(2\rho^2 - 2r_o + R^2) \qquad (20)$$

$$F_c = 2.229 \times 10^{-5}\,WN^2R^2\,(2\rho^2 - 2r_o + R^2) \qquad (21)$$

The methods outlined can usually be adapted to special cases which are likely to be encountered by the designer from time to time.

Diaphragm Cylinders: Diaphragm type pistons are widely used where cost is important and where the ratio of bore to stroke is such that a flexible diaphragm can be used to replace a solid piston.

This discussion is mainly concerned with pressure due to centrifugal forces but it is worthwhile to develop first an expression for the total force on a diaphragm piston due to uniform applied pressure. The analysis of a diaphragm cylinder is of necessity divided into two parts: the contribu-

tion of the diaphragm portion to the total force on the piston rod; and the contribution of the clamping plates or rigid portion of the piston to the total force.

STATIC PRESSURE FORCES: In *Fig.* 13, on an elemental area of the diaphragm, dA, the force acting will equal pdA. Now, for an isolated radial segment of the diaphragm *abcd*, not all of the force acting on the area dA will be applied to the piston rod: a fraction of it will be taken in the form of a reaction on the cylinder wall and the remainder will constitute an effective contribution to the piston rod force. *Fig.* 14 shows a radial section through the segment *abcd*. For purposes of analysis the segment may be regarded as a simply supported beam with a concentrated load pdA at a radius r. Thus, the effect of the diaphragm force on the piston rod can be expressed by

$$dF_d = p_a dA \left(\frac{R_o - r}{R_o - R_i} \right)$$

To obtain the total force on the piston rod due to pressure acting on the diaphragm the foregoing expression is integrated over the area of the diaphragm:

$$F_d = \int_o^{2\pi} \int_{R_i}^{R_o} p_a \left(\frac{R_o - r}{R_o - R_i} \right) dA$$

Subsitituting $dA = r d\theta dr$:

$$F_d = \frac{p_a}{R_o - R_i} \int_o^{2\pi} \int_{R_i}^{R} (R_o - r)\, r\, dr\, d\theta \qquad (22)$$

Integration of Equation 22 yields

$$F_d = \frac{\pi p_a}{3} (R_o^2 + R_o R_i - 2R_i^2) \qquad (23)$$

To obtain the total force on the piston rod the contribution of the rigid center plate portion of the piston must be added:

$$F_p = p_a \times A = p_a \pi R_i^2$$

Total force is

$$F_a = \frac{\pi p_a}{3} (R_o^2 + R_o R_i - 2R_i^2 + 3R_i^2)$$

$$F_a = \frac{\pi p_a}{3} (R_o^2 + R_o R_i + R_i^2) \qquad (24)$$

Equation 24 gives the total force on the piston rod in a diaphragm cylinder for a given applied pressure. Where a relationship between a solid piston and a diaphragm piston is sought, it is convenient to convert Equation 24 to a more suitable form by introducing a few simple substitutions. Let $k = R_i/R_o$, or $R_i = kR_o$ then substitute into Equation 24:

$$F_a = \frac{\pi p_a}{3} (R_o^2 + kR_o^2 + k^2 R_o^2)$$

$$= \frac{\pi p_a}{3} R_o^2 (1 + k + k^2) \qquad (25)$$

Now let $y = \frac{1}{3}(1 + k + k^2)$. Equation 25 becomes

$$F_a = \pi p_a R_o^2 y \qquad (26)$$

However, the force on a solid piston of radius R_s would equal $\pi p_a R_s^2$. Equating this to Equation 26,

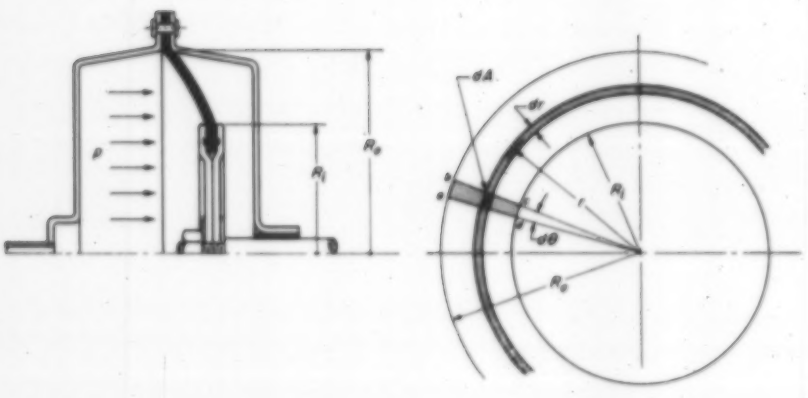


Fig. 13—Force acting on a diaphragm piston includes all of the pressure on the rigid piston plus a portion of that on the diaphragm. For static pressure p, Equation 24 gives total force

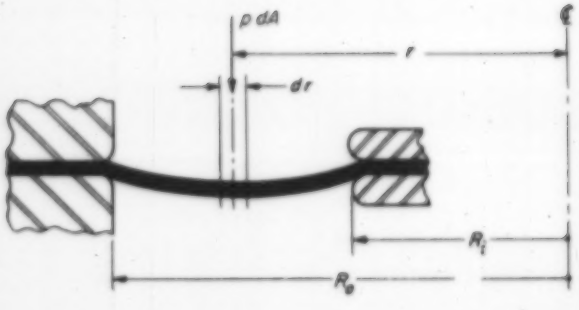


Fig. 14—Diaphragm between clamps is assumed to act as a simply supported beam with a concentrated load pdA at radius r from the axis

$$R_s^2 = R_o^2 y \qquad (27)$$

Where R_s is the radius of a solid piston which would give the same force as a diaphragm piston of maximum diaphragm radius, R_o. Stated another way, the effective area of the diaphragm piston is reduced by the factor y.

In design of a diaphragm cylinder to give a certain required force on the piston rod, Equation 25 is used directly to obtain R_o with an assumed value of k. The value of k will generally depend on the stroke and the flexibility of the diaphragm and must not be too large in order to permit free movement of the piston. However, small values of k should also be avoided since they result in higher stresses in the diaphragm.

Values of $y = \frac{1}{3}(1 + k + k^2)$ are plotted in *Fig.* 15 against k. This will aid the designer in computing the force on the piston rod and in finding equivalent solid pistons.

The volumetric displacement of a diaphragm cylinder may also be easily calculated by the use of the factor y. Examination of Equation 26 shows that the factor y modifies the outside radius of the cylinder, R_o, to make it equivalent to the radius of a solid piston of dimensions $R_o\sqrt{y}$. The two cylinders in *Fig.* 16 will have equal displacements and the work done by the piston on the fluid (or vice versa) is equal in both cases provided the strokes are equal. Therefore, displacement of a diaphragm type cylinder is given by

$$V = \pi R_o^2 y L \qquad (28)$$

It should be borne in mind that the foregoing section of the diaphragm analysis applies to both pneumatic and hydraulic operations. However, the following discussion dealing with rotative forces is valid only for comparatively incompressible fluids such as water or oil. For practical purposes compressible fluids such as air or other gases would have little or no centrifugal effect in most applications.

CENTRIFUGAL PRESSURE FORCES: Conditions here are similiar to those encountered in deriving Equation 24, the only difference being that the pressure is not constant but varies according to the equations derived in the earlier part of this article. Referring to *Fig.* 14, the force due to pressure acting on the elemental area dA which is transmitted to the piston rod is

$$dF_d = p dA \left(\frac{R_o - r}{R_o - R_i} \right)$$

where p, for centrifugal force, equals $\frac{1}{2} m \omega^2 r^2$ (Equation 4) and $dA = r d\theta dr$. Substituting,

$$dF_d = \frac{m \omega^2}{2} r^3 \left(\frac{R_o - r}{R_o - R_i} \right) d\theta \, dr$$

The contribution of the whole diaphragm to the total force is obtained by integrating this expression over the area of the diaphragm:

$$F_d = \frac{m \omega^2}{2(R_o - R_i)} \int_o^{2\pi} \int_{R_i}^{R_o} (R_o - r) r^3 d\theta dr$$

$$F_d = \frac{\pi m \omega^2}{20} (R_o^4 + R_o^3 R_i + R_o^2 R_i^2 + R_o R_i^3 - 4R_i^4)$$

Fig. 15—Factor y is a measure of the reduction in effective area of a nonrotating diaphragm cylinder as R_i is decreased in relation to R_o, *Fig.* 13. See Equations 26 and 27

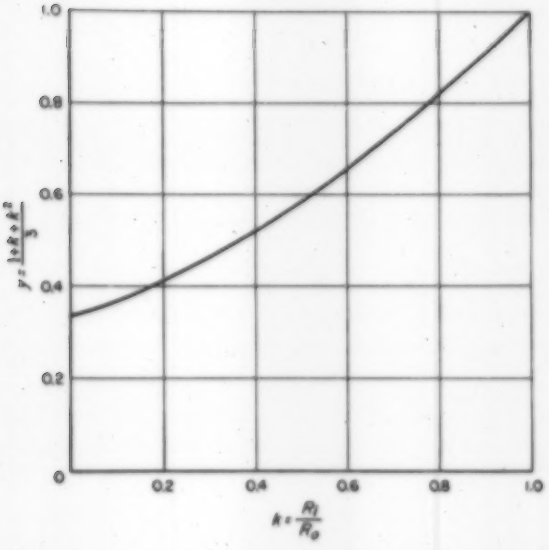
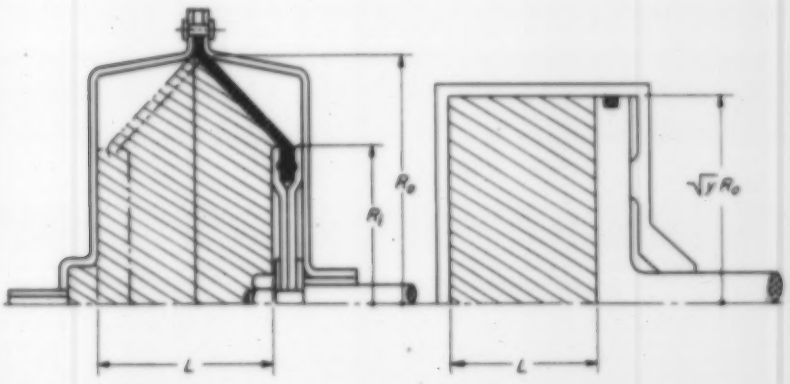


Fig. 16—Diaphragm piston and solid piston have equal force and volumetric displacement if the relative proportions are as shown. Factor y is given in *Fig.* 15



Now using Equation 6, the force provided by the center plates is

$$F_p = \frac{\pi m \omega^2}{4} R_i^4$$

Adding F_p to F_d,

$$F_c = \frac{\pi m \omega^2}{20} (R_o^4 + R_o^3 R_i + R_o^2 R_i^2 + R_o R_i^3 + R_i^4) \quad (29)$$

Making the substitution, $R_i = kR_o$:

$$F_c = \frac{\pi m \omega^2}{20} R_o^4 (1 + k + k^2 + k^3 + k^4) \quad (30)$$

$$F_c = \frac{\pi m \omega^2}{4} R_o^4 x \quad (31)$$

where $x = 1/5 (1 + k + k^2 + k^3 + k^4)$. Conversion to practical units gives

$$F_c = 2.229 \times 10^{-5} WN^2 R_o^4 x \quad (32)$$

Factor x is plotted in *Fig.* 17 for all values of k. Notice that Equation 32 gives only centrifugal forces. To find piston rod force due to both centrifugal and applied pressure it is necessary to add F_c to F_a.

An example will serve to illustrate some of the points just discussed. What bore would a solid piston-type cylinder have to be if it is to replace a diaphragm cylinder having a diaphragm of 8 inches maximum diameter and center plates of 5 inches diameter?

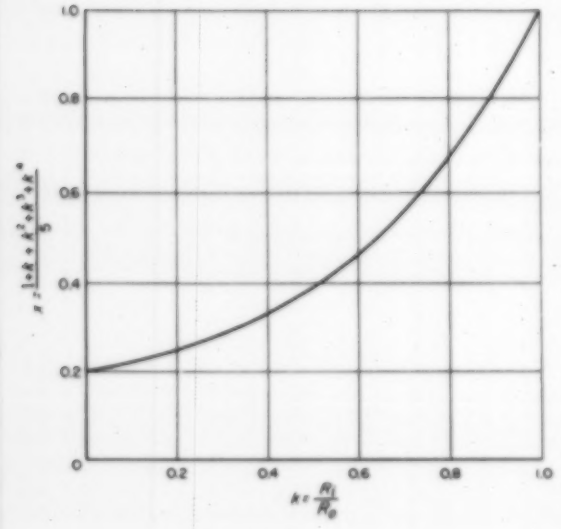


Fig. 17—Factor x is a measure of the reduction in force on a rotating diaphragm cylinder as R_i is decreased in relation to R_o. *Fig.* 13. See Equation 32

Inasmuch as $R_i = 2.50$ and $R_o = 4.0$, k equals 0.625. Three different conditions could exist at this point, each of which must be treated in a somwhat different manner.

First, if the cylinders are not rotating and there is only applied pressure acting on the pistons, Equation 27 and *Fig.* 15 apply. From *Fig.* 15, when $k = 0.625$, y would equal 0.675. Substituting in Equation 27 $R_x^2 = 0.675(4^2) = 10.8$ and $R_x = 3.285$.

Second, if the cylinders are subject to centrifugal pressures only, equating Equations 6 and 31 would give $R_x^4 = xR_o^4$. Then, from *Fig.* 17, $x = 0.482$ when $k = 0.625$. Substitution gives $R_x^4 = 0.482 (4^4) = 123.4$ and $R_x = 3.333$.

The third condition includes both of the foregoing conditions where the cylinders are subject to both centrifugal and applied pressure. It is apparent that the value of R_x in this case will fall between 3.285 and 3.333. Since these values are rather close together, R_x could be taken as the mean value with very little error. This would give $R_x = 3.314$ inches. For values of k greater than 0.5 this approximation is usually accurate enough for most purposes. However, if an exact computation is needed it can be found by equating the force of one cylinder to the force of the other.

Force on the solid piston is

$$F_{c+a} = 2.229 \times 10^{-5} WN^2 R_x^4 + p_a \pi R_x^2$$

Force on the diaphragm piston is

$$F_{c+a} = 2.229 \times 10^{-5} WN^2 R_o^4 x + p_a \pi R_o^2 y$$

Let $W = 0.03$ lb per cubic inch, $N = 3000$ rpm, and the applied pressure $p_a = 40$ psi (factors x and y do not change); evaluate the two force equations then set them equal to each other.

Force on the solid piston is

$$F_{c+a} = 6.018 R_x^4 + 125.66 R_x^2$$

Force on the diaphragm piston is

$$F_{c+a} = (6.018)(4^4)(.482) + (125.66)(4^2)(.675) = 2099.69$$

Equating,

$$6.018 R_x^4 + 125.66 R_x^2 = 2099.69$$

Solving this equation by the quadratic formula and discarding the negative answer give $R_x = 3.310$ inches. This compares with 3.314 when the simple mean value was taken.

They Say . . .

"Arts and sciences are not cast in a mold, but are formed and perfected by degrees, by often handling and polishing, as bears leisurely lick their cubs into form."—MICHEL DE MONTAIGNE.

Design Recommendations for

Aluminum Bearings

Possibilities and limiting conditions for aluminum and aluminum on steel journal bearings

By J. B. Mohler
Consultant
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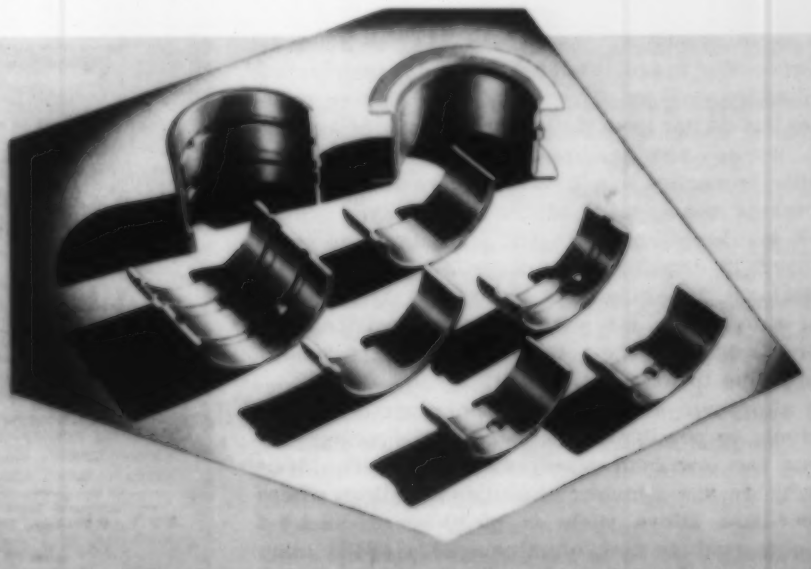
ALUMINUM sleeve bearings now have a history and a reputation. Aluminum bearings and bushings have been used by the millions for diesel-engine main, connecting-rod and camshaft applications. In several applications, aluminum has given better service than any other material tried. In recent years aluminum on a steel back has gained a similar reputation in diesel and gasoline engines.

Since aluminum has been successfully used for connecting-rod bearings it apparently has the properties demanded of a bearing material under relatively severe demands for load, speed and surface properties.[1] Certainly, it can be used under less severe conditions or for higher loads at reduced speeds. This article will discuss present design practices with regard to aluminum bearings, and give basic recommendations for aluminum and aluminum on steel bearings.

Aluminum Bearing Alloys: At the present time there are several aluminum bearing alloys in commercial use. One alloy is essentially an aluminum-

[1]References are tabulated at end of article.



Aluminum-lined steel-backed diesel-engine bearings are used at relatively high speeds and loads

Bearings successfully used in a gasoline truck engine are steel backed and aluminum lined

tin alloy and the other an aluminum-silicon alloy. Seizure testing has shown that both tin and silicon additions will increase seizure resistance.

Two aluminum-tin alloys are available known as Alcoa 750 and X8280 (XB80S), both with a nominal tin composition of 6.5 per cent. The 750 alloy is a cast alloy containing small amounts of copper and nickel to increase strength, hardness, and resistance to scuffing. The 8280 alloy is a wrought alloy similar to 750 with a small amount of silicon added to overcome problems of hot shortness encountered in production of rolled 750 sheet.

The other commercial aluminum alloy is an alloy containing 4 per cent silicon and 1 per cent cadmium,[2] used for making steel-backed bearings with a lead-tin overlay.[3]

These alloys are intended for duty in internal-combustion engines. They have good seizure resistance but do not have the seizure resistance, conformability, or embeddability of the babbitts. These desirable properties can be made more favorable by increasing the amount of tin in the alloy. Some work has been done with tin contents of 20 to 25 per cent in aluminum-tin-copper alloys by the International Tin Research Institute. Alloys have been successfully cast with these compositions, but attempts to clad them to steel have been unsuccessful due to loss of tin.

If aluminum is a general bearing material then it should be possible to use some of the commercial alloys for low load requirements. It should be possible to use commercial aluminum alloys where copper-base alloys such as 80-10-10 or 88-4-4-4 are now used. In fact, aluminum 2024 (24S) alloy has been successfully run as an electric motor bushing, although it is not in commercial use. It is thought that 2024 (24S), 5052 (52S) and 6061 (61S) are all possibilities for bushing applications.

Laboratory work is being continued to measure the bearing properties of commercial and experimental aluminum alloys. In the meantime, a look at the record will indicate new applications for existing proved alloys.

LOAD CAPACITY: Rated load capacities based on test results from various sources for connecting-rod bearings are indicated in *Table* 1. These are merely considered as safe maximum loads.

These tests indicate that aluminum may have longer fatigue life than copper-lead with an overlay. Bearing fatigue tests run in an Underwood bearing testing machine are shown in *Table* 2. It was found that, with these rather severe accelerated test conditions, the overlay on the copper-lead had a short life and that the copper-lead started to run hot and fatigue rapidly after the overlay was gone. Under less severe conditions it is expected that the comparison will be more favorable for the copper-lead composition. On the other hand, the aluminum did run at much higher loads under the same conditions and without an overlay.

In the tests run at 6000 psi, the aluminum was pounded down in the high load area and developed cracks parallel to and near the bond line. At 5000 psi the failures had the appearance of typical fatigue. It was concluded that, at 6000 psi, resistance to pounding was being measured and that fatigue tests should not be run above 5000 psi.

Table 1—Load Capacities of Steel-Backed Bearings

Material	Load Capacity* (psi)
Babbitt, 0.010-0.020-in. thick	1500
Babbitt, 0.002-0.005-in. thick	2000
Copper-lead, SAE 48	3000
Solid aluminum	3500
Copper-lead overlay	4000
Aluminum on steel	4000

*1000 hours; normal operation.

Table 2—Fatigue Tests on Steel-Backed Bearings*

Bearing	Test Load (psi)	Individual Running Times (hours)	Average Running Time hours)
SAE 14 babbitt, 0.005-in. thick	2400	50, 52	51
SAE 14 babbitt, 0.005-in. thick	3000	2, 11	6.5
65-35 copper-lead	3000	5, 16, 17, 24	16
75-24 copper-lead with 0.001-in. lead-tin overlay	3000	50, 68	59
X8280 (XB80S) aluminum	5000	60, 78	69
X8280 (XB80S) aluminum	6000	11, 21, 41	24

*Accelerated tests run on Underwood bearing tester at 4150 rpm, 350 F, 0.0015-in. bearing clearance, and 10 microinch max journal finish.

These tests indicate that the recommended maximum of 4000 psi could be increased, and that aluminum has enough extra load capacity to take care of the extra horsepower that is being designed into modern engines.

It can also be concluded that the X8280 alloy can be used at higher loads at lower surface speeds. If appreciably greater loads are involved, then an alloy of higher yield strength would be required. Yield strength of the aluminum alloys can be raised by addition of copper, silicon, magnesium and nickel, although the hard aluminum alloys cannot be compared to the hard copper alloys, and load-carrying capacity will probably be less than in applications where the bronzes are now used.

SEIZURE RESISTANCE: When bearing tests were run for the conditions given in *Table* 2, but with journal finishes of 10 to 15 microinches, seizures occurred. Under these conditions, journal finish was a limiting factor. However, seizures were also obtained with copper-lead. One seizure was obtained with the 65-35 alloy used without an overlay. It was concluded that the seizure resistance of the 8280 alloy probably lies between that of 65-35 and 76-24 copper-lead. Copper-lead depends on the presence of lead for seizure resistance. Since the lead is subject to corrosion, and may be lost from the surface, resistance to seizure decreases with use. However, there is less need for resistance to seizure as the bearings wear in. But, of course, if lead is lost from the surface the remaining copper constituent will cause increased rate of wear on the journal.

Aluminum-tin alloys contain only a small amount of tin so the aluminum matrix must be seizure-resistant in itself. However, the tin does add seizure resistance, and since the tin and the aluminum matrix are both resistant to corrosion, seizure resistance should not decrease with time.

Where seizure resistance of aluminum alloys is not adequate, it may be increased for low-load applications by using a high tin alloy or, for high-load applications, by using an overlay.

OVERLAYS: Overlays definitely increase fatigue life of copper-lead alloys. Apparently they delay the start of initial cracks by acting as a low-friction surface. Testing of aluminum alloys with overlays has not indicated a gain in fatigue life due to the presence of an overlay. Therefore, not much is gained by use of an overlay.

Yet there have been many examples where aluminum bearings would seize unless an overlay was used. Apparently the overlay serves as a break-in surface. After the overlay is gone, the good seating and increased clearance obtained from wearing in are sufficient that the bearings will continue to run. The overlay also increases ability of the bearing to embed dirt. It is desirable to have an overlay thickness as great as the maximum size particle passed by the oil filter.[4]

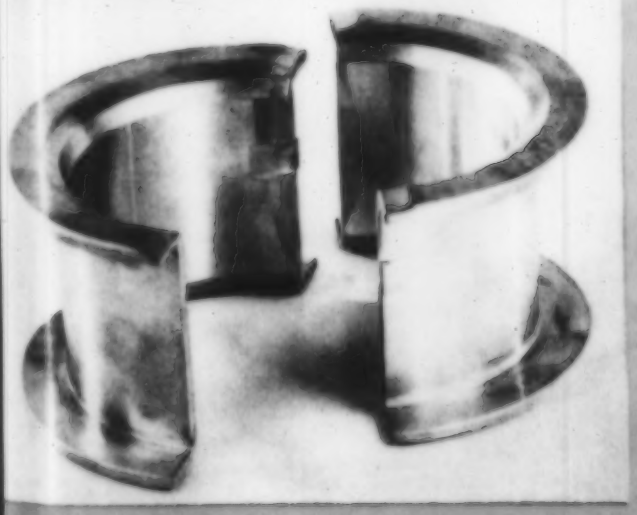
ALIGNMENT: In one bearing test, a set of bearings with a lead-alloy overlay were installed with zero clearance within the limits of measurement. The bearings ran hot and wore rapidly, but they did not seize. Such conditions would produce seizure with bearing alloys other than those of lead and tin.

One of the main bearings on the bearing testing machine was subject to edge loading due to pressure from the belt that drove the shaft. Babbitt bearings would run in this position until they were extensively fatigued. Aluminum X8280 bearings ran for several hours and then seized. Aluminum 8280 bearings with a tin overlay ran for a relatively long time and even after the overlay was worn away near the edge. Eventually however, they began to run hot. Performance of the main bearings, subjected to edge loading, demonstrated the capacity of high-load overlay bearings to run under conditions of uneven load. Also, it was demonstrated that aluminum alloys will seize due to such conditions.

On the other hand it was apparent that the aluminum alloys had some tolerance for misalignment. The bearings were all steel-backed bearings. It has also been found under conditions of poor alignment that solid aluminum bearings will not seize as readily as aluminum on steel. This is because solid aluminum bearings will conform better than aluminum on steel. Solid aluminum bearings have a large mass that is capable of movement under pressure whereas the aluminum on steel is restricted by the hard backing.

If aluminum bearings are to be used, bore, taper and out-of-round tolerances for the housing, the

Heavy wall aluminum-lined steel-backed bearing formed from flat stock, illustrating the forming possibilities of combining these metals



journal and the bearing should be such that edge loading or local overloading due to improper fits will be avoided Modern instrumentation and quality control are definite aids to assure better fits, and considerable progress has been made along these lines in the past decade. These factors may easily account for the relatively recent success of aluminum bearings.

EMBEDDABILITY: Since aluminum is a relatively soft material, it has a greater ability to engulf dirt particles than the harder copper alloys. Considering that copper-lead alloys are used without an overlay and that solid aluminum has been so used successfully, it is obvious that aluminum has sufficient embeddability for many applications. On the other hand, embeddability can be improved by the use of an overlay. An overlay thickness of 0.0005-inch will improve embeddability, although 0.001-inch is more effective. Since improvement in embeddability in dependent on overlay thickness, and since the overlay is thin, loss of this property will be appreciable for a small amount of wear when an overlay is used.

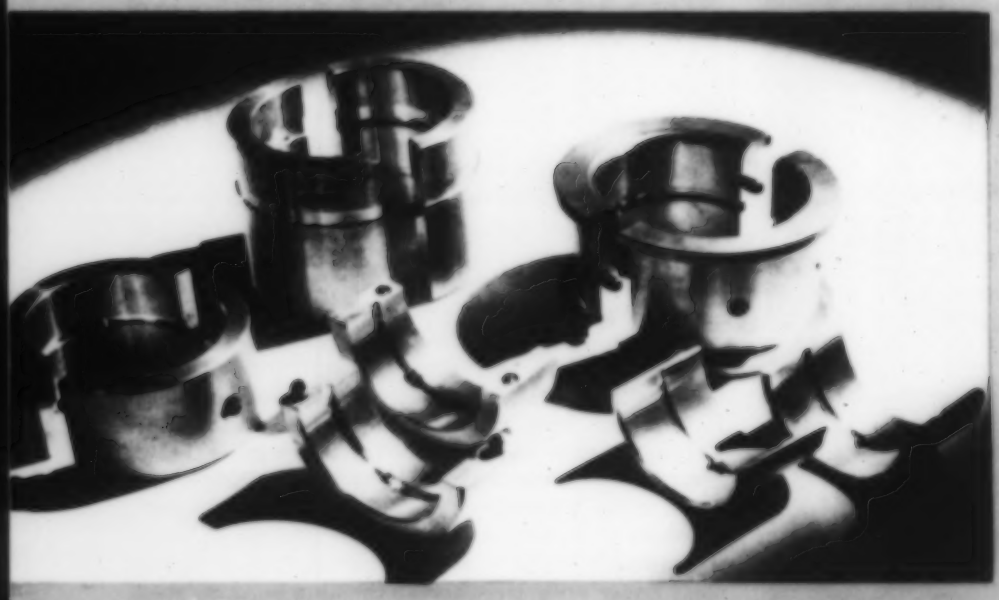
SPEED: Aluminum bearings will run successfully at surface speeds that are common for internal combustion engines, at the loads encountered in such engines. At lower loads they may be run at higher speeds. Or, by the use of high tin alloys or overlays, they may be run at higher speeds. In high-speed applications, misalignment or the presence of dirt become important factors due to the possibility of building up heat more rapidly.

CORROSION: Corrosion is a problem with the copper-leads and to a lesser extent with the lead-base babbitts. Aluminum is fundamentally a corrodible alloy. But experience has shown that for the conditions normally encountered in an engine, corrosion resistance is excellent.

SHAFT FINISH: Problems of shaft hardness are not adequately understood. Certain limitations have been recommended in terms of the finish in microinches. If this value is placed sufficiently low, for normal grinding practice and a given shaft hardness, seizure may be avoided. The same surface finish obtained by a polishing method or obtained on a soft shaft may not guarantee freedom from trouble. It is believed that shaft hardness and surface finish may be related; that the desired type of finish is more easily obtained on a harder shaft. General recommendations may be made but more information on results obtained with different methods of finishing would be desirable.

Test results indicate that a worn-in shaft that is not excessively scored will be less liable to promote seizure than a freshly ground shaft. Indications are that a new set of bearings will be less liable to promote heat on such a shaft than on a new shaft. On the other hand a new set of bearings may seize on a used shaft that is galled.

WEAR: In the use of sleeve bearings, wear is inevitable. Bearings wear and the shaft wears, and amount of wear depends greatly on the amount of dirt present. Resistance to wear depends primarily on hardness. It is much better to allow a soft bearing to wear, and prevent shaft wear, than to use a harder bearing at the expense of shaft wear. After all it is much more economical to replace bearings than to regrind the shaft. Also, the soft bearing will engulf dirt, whereas a hard bearing will hold the dirt at the surface and increase abrasive wear. Aluminum is kind to the shaft because it is relatively soft, yet it is sufficiently hard that



Solid aluminum bearings with heavy walls, used for many years at moderate loads and speeds in diesel engine service

its wear rate is not excessive.

General Design: The problems of lubrication, oil grooving and clearance are essentially the same for aluminum on steel bearings as for other high-load steel-backed bearings.

TEMPERATURE: Load capacity of bearings decreases with increase in temperature. This is particularly noticeable with the babbitts. It may be taken as a general rule that this loss of properties with increase in temperature can be approximated from the difference in operating temperature as compared to the melting point of the alloy. The melting point of aluminum is sufficiently high that there is no serious loss due to normal operating temperatures.

Expansion of aluminum due to increase in temperature during operation must be taken into consideration. With thin aluminum and a steel back it need not be considered, but with heavy aluminum, a sufficient temperature rise could result in complete loss of clearance. In this case, sufficient extra clearance must be allowed for the difference in coefficient of expansion between the aluminum bearing and the housing. However, the calculation should be made so that the clearance is normal after the bearing has come up to operating temperature. This property of aluminum may be somewhat of an advantage since the clearance would be greater for initial starting and cold oil, than for operating conditions.

OPERATING CONDITIONS: Final acceptance of a new or different bearing material will depend on an acceptance test. But such a test is expensive and one of the last stages of a testing program. The first step is to make an estimate from existing information of the probable limiting conditions of the bearing material.

Estimated limiting conditions for an accelerated test and an endurance test of steel-backed aluminum bearings are shown in *Table* 3. Estimated conditions for the accelerated test are for the X8280 alloy are close to those obtained by Underwood testing. To safely pass a 1000-hour endurance test, it was estimated that under slightly more stringent conditions, the load would have to be reduced by about ⅓. It should be noted that in the accelerated test the bearings were run to destruction whereas in the endurance test they are still capable of operation after 1000 hours.

From the same data, the limiting speeds for operation at various loads are shown in *Table* 4 for a 2⅜-inch shaft, using a *PV* value of 145,000. Such data can be calculated for other shaft sizes from the *PV* values of *Table* 3. However, the proportionality should not be applied above 5000 psi since the Underwood test data indicates that the 8280 alloy will pound out at higher loads. For higher loads a harder alloy might be considered.

It is assumed that the accelerated test data cannot be safely exceeded as a maximum condition without danger of seizure. Under less severe conditions some leeway may be allowed, such as more tolerance on the shaft finish. However, this should not be greatly increased. It has been recommended

Table 3—Estimated Limiting Test Conditions for Aluminum on Steel Bearings*

	Accelerated Test†	Endurance Test
Bearing Data		
Shaft diam, in.	2⅜	2⅜
Clearance, in.	0.0015	0.002
Shaft finish, microinches	10	10
Limiting Test Conditions		
Time, hr	50	1000
Temperature, deg F	350	250
Load, psi	5200	3500
Speed, rpm	4150	4000
PV value, psi × ft/sec	228,000	145,000

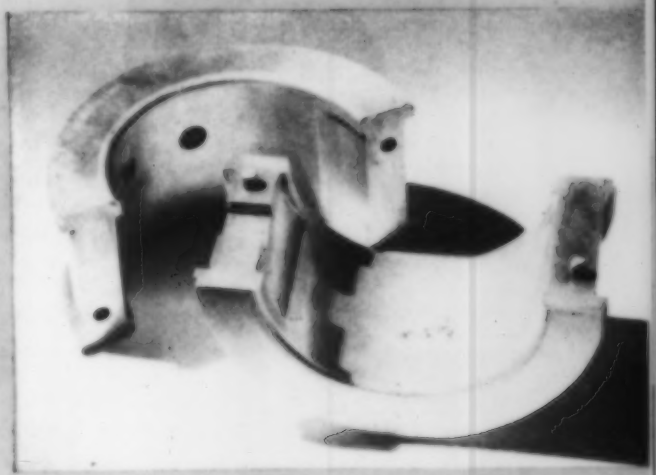
*X8280 (XB808) aluminum alloy. †See *Table* 2.

Table 4—Operating Speeds and Loads*

Load (psi)	Speed (rpm)
1000	14 000
2000	7 000
3000	4 700
4000	3 500
5000	2 800

*For 2⅜ in. diam shaft.

Method of pinning the halves of a heavy-wall aluminum bearing with a steel pin



that the shaft hardness be 165 brinell minimum for large diesel engines and 450 brinell minimum for high-speed engines. A finish of 10 microinches is recommended with 20 microinches acceptable.

Maximum recommended load capacity for the aluminum-tin alloys is 4000 psi for cast aluminum and 5000 psi for aluminum on steel. Safe maximum speeds can be calculated from the *PV* values. Tentative clearances of 0.00075-inch per inch of shaft diameter with an overlay, and 0.001-inch of shaft diameter without an overlay, have been recommended. In the case of solid aluminum, extra clearance should be calculated to allow for thermal expansion.

The overlay may be 0.0005 to 0.001-inch for small shafts and 0.001 to 0.002-inch for large shafts. The overlay may be tin or lead-tin.

For high-speed high-load applications, the aluminum-tin or aluminum-silicon alloys are recommended.

These recommended conditions are considered to be safe limitations and a starting point for the design of test bearings. In a testing program, it will probably be found that the maximum conditions can be exceeded. In the meantime it is best to play safe until more is learned about the limitations and applications of aluminum bearing alloys.

ACKNOWLEDGMENT

The author is indebted to the Johnson Bronze Co. for data and illustrations used in this article.

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2. U. S. Patent 2,238,399.
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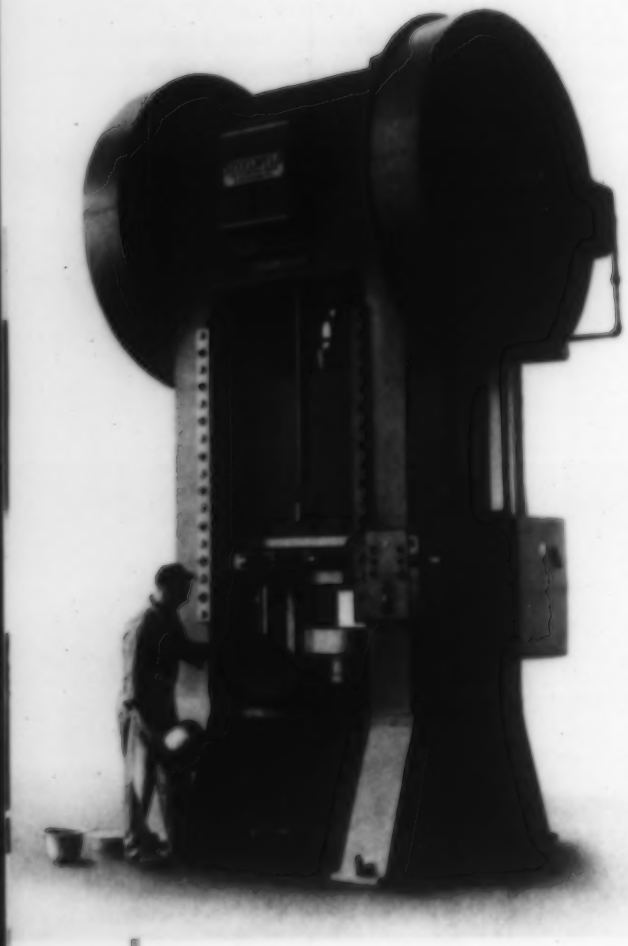
CONTEMPORARY DESIGN



Press Design Reduces Nonproductive Time

A RECENTLY introduced line of deep-drawing presses incorporates a linkage that varies ram speed during the press stroke to provide high approach and return speeds and a slower, correct drawing speed during the working portion of the stroke. Operating speeds up to 80 per cent greater than the conventional crank press are claimed although actual drawing speed remains the same. Sizes range from 160-ton capacity up according to the manufacturer, Steelweld Machinery Div., Cleveland Crane & Engineering Co. The mechanism has been applied to single-acting and double-acting, one, two and four-point presses.

A function generator for quickly drawing an atlas of input-output curves means a versatile graphical method for

Designing Four-Bar Linkages

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Fig. 1 — Four-bar linkage function generator for developing atlas of linkage curves

SIMPLICITY of construction, efficiency of operation, dependability, low maintenance, low inertia effects, and freedom from wear are the design advantages of the bar link, if properly designed. Although the bar *link* is widely used in mechanisms and machines, full potential of the bar *linkage* is usually not exploited because of lack of knowledge of the relative motions involved.

Motion analysis of a given bar linkage is relatively simple, but from given motion specifications, it is not correspondingly simple to design the linkage to produce the required motion with the desired degree of accuracy. This fact suggests a technique for synthesizing a four-bar linkage—making an educated guess at a design and then analyzing it to determine its suitability. If this were done systematically and the results of each trial design plotted, then these graphs could be used as bases for subsequent designs and eventually produce a satisfactory design. Time and graphical work necessary might be greatly reduced if certain aids were available and were used. The *Atlas* compiled by Hrones and Nelson* may be used to advantage.

Another kind of atlas of considerable assistance in the synthesis of four-bar linkages will be proposed in this article. Used in the development of an atlas is an instrument for generating the curves of angular displacement of one crank versus the angular displacement of the other. How these curves, compiled into an atlas, can be used to solve two kinds of problems will be demonstrated: (1) Design of a four-bar linkage which will cause a certain point on the coupler to follow a required

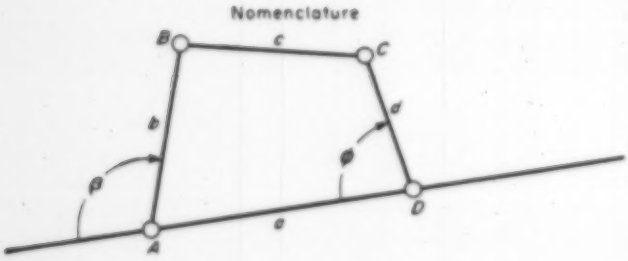
*J. A. Hrones and G. L. Nelson—*Analysis of the Four-Bar Linkage*, John Wiley and Sons Inc., New York, and Technology Press of Massachusetts Institute of Technology, 1951.

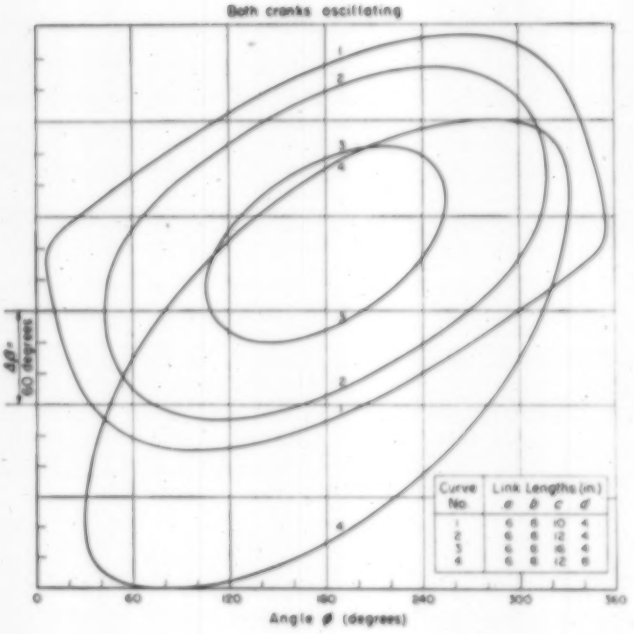
path and (2) design of a four-bar linkage which will generate a required functional relationship between the input and output parameters.

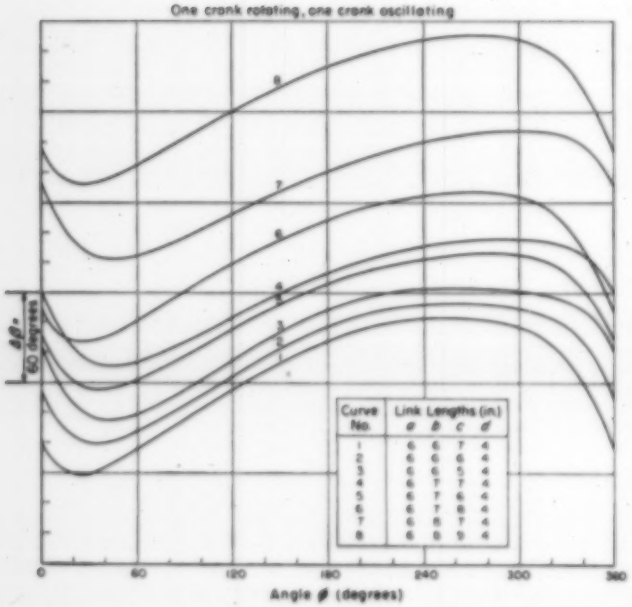
Atlas Plan: The function generator, *Fig.* 1, is used for mechanically drawing curves such as shown in *Fig.* 2. An atlas consists of curves of angle β versus angle ϕ. Since this angular relationship remains the same for all possible inversions of the linkage, the curve need be plotted for only one inversion. The curves in an atlas should be divided into the following three main groups:

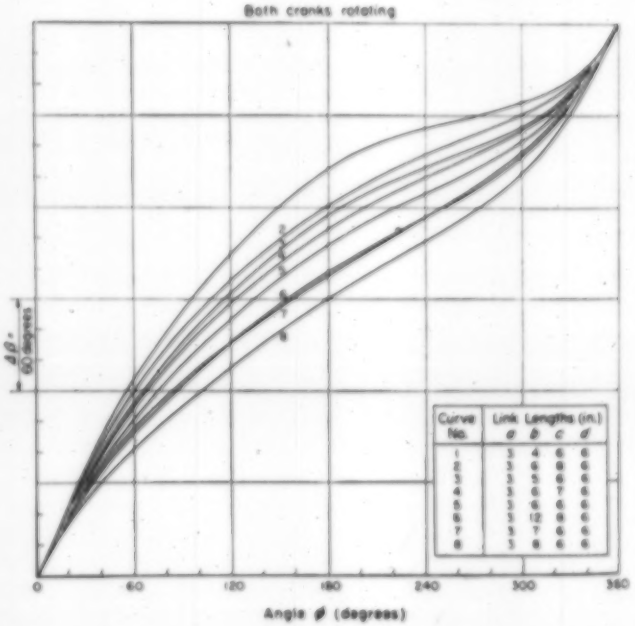
1. Cranks *b* and *d* oscillating only
2. Either crank *b* or *d* rotating completely and the other oscillating
3. Both cranks making complete rotations, (drag-linkage)

Fig. 2—Atlas details. Linkage gives symbols for angular-position reference angles, links and pivots. Originals of atlas curves are drawn on commercially available graph paper with heavy lines 1 inch apart, light lines 0.1-inch apart. Original scale is 1 inch = 20 degrees. For convenience in grouping a number of curves on one sheet, the origin of the β axis is shifted up or down for the different curves. The β origin can be determined by measuring or calculating one ϕ, β co-ordinate from the linkage




Both cranks oscillating
Δβ - 60 degrees
Curve No.
Link Lengths (in.)
a b c d
1 6 6 10 4
2 6 6 12 4
3 6 6 16 4
4 6 6 12 6
0 60 120 180 240 300 360
Angle φ (degrees)


One crank rotating, one crank oscillating
Δβ - 60 degrees
Curve No.
Link Lengths (in.)
a b c d
1 6 6 7 4
2 6 6 6 4
3 6 6 5 4
4 6 7 7 4
5 6 7 6 4
6 6 7 8 4
7 6 8 7 4
8 6 8 9 4
0 60 120 180 240 300 360
Angle φ (degrees)

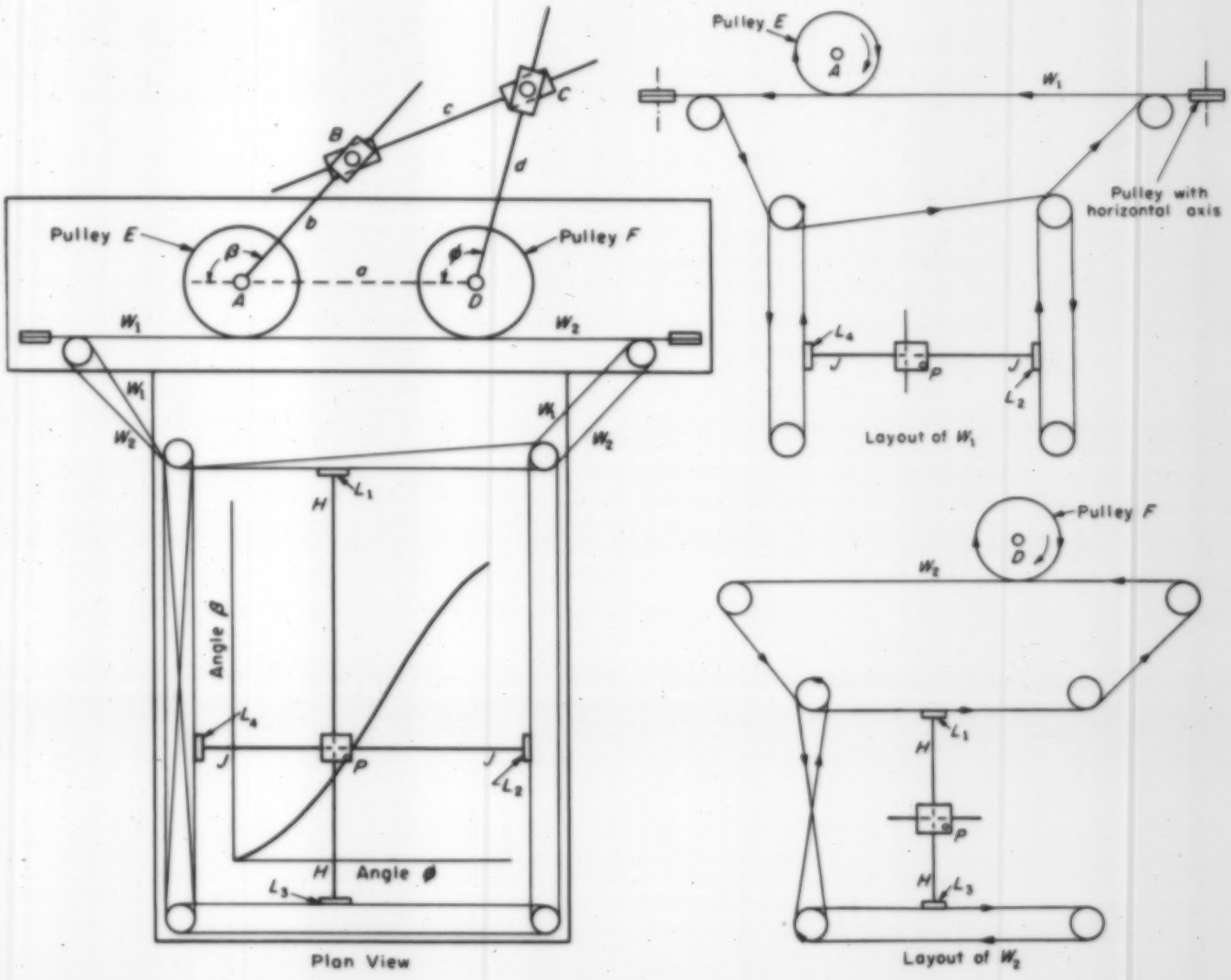

Both cranks rotating
Δβ - 60 degrees
Curve No.
Link Lengths (in.)
a b c d
1 3 4 6 6
2 3 6 8 6
3 3 5 6 6
4 3 6 7 6
5 3 6 6 6
6 3 12 8 6
7 3 7 6 6
8 3 8 6 6
0 60 120 180 240 300 360
Angle φ (degrees)

Each main division of an atlas should consist of a series of curve families. Each family should have the same values for two of the three link ratios: b/a, c/a, d/a. The third ratio should vary throughout each family over a predetermined range. The curves should be so drawn on graph paper to permit interpolation.

Function Generator: The detail drawings, *Fig.* 3, show how the function generator operates. The four-bar linkage is *abcd*. The other parts shown are required to transform and transmit angular motions of the cranks to linear motions of the tracing pen *P*. Pen *P* is mounted in such a way that it is always at the intersection of the guide axes *H-H* and *J-J*. The guides are supported by rollers L_1, L_2, L_3, L_4. Wires W_1 and W_2 move the guides in a plane parallel to the plane of the graph paper and the four-bar linkage, *abcd*. Pulleys *E* and *F* are approximately 6 inches in diameter. Links *b* and *d* rotate pulleys *E* and *F*, respectively, about axes *A* and *D*. The other pulleys which carry wires W_1 and W_2 have fixed axes and are 2 inches in diameter.

The continuous wire W_1 makes one complete turn around pulley *E* and then travels via the smaller pulleys to both ends of guide *J-J* and back to pulley E. Similarly, wire W_2 passes around pulley *F* and travels via smaller pulleys to both ends of guide *H-H* and back to pulley *F*. Wires W_1 and W_2 are in no way connected and they run on separate pulleys. Wherever a wire W_1 must pass around the same pulley more than once, the wire is wrapped around the pulley always in the same direction. When pulley *E* is rotated by crank *b*, wire W_1 causes *J-J* to move perpendicular to itself

Fig. 3—Details of four-bar linkage function generator



through friction between wire W_1 and pulley E. Similarly rotation of F causes guide H-H to move perpendicular to itself. The pivots A and D are movable so that the length of link a can be changed. Length of links b c, and d can also be varied at will. Pivots A and D are mounted in such a way that complete rotations of b and d are possible.

Designing Point Paths: An atlas might be used in the design of a four-bar linkage required to produce a specified path of travel for a point. Suppose the required path is a straight line. That is, some point on the connecting rod is required to travel a straight-line path.

The first step, *Fig.* 4, is to choose a reference line OZ, a crank of some convenient length OA, and one side AE of the coupler triangle.† Locate the required path XY as desired relative to the reference line OZ. (*Fig.* 4) Now determine the values of angles ϕ and β for successive positions of E along the path XY. Angle ϕ is then plotted on transparent paper, *Fig.* 5, against angle β to the same scale that the curves in the atlas are plotted. Curves in *Fig.* 2 are miniatures from the proposed atlas.

†Kurt Hain—*Angewandte Getriebelehre*, 1952. Hermann Behroedel, Hannover. Darmstadt.

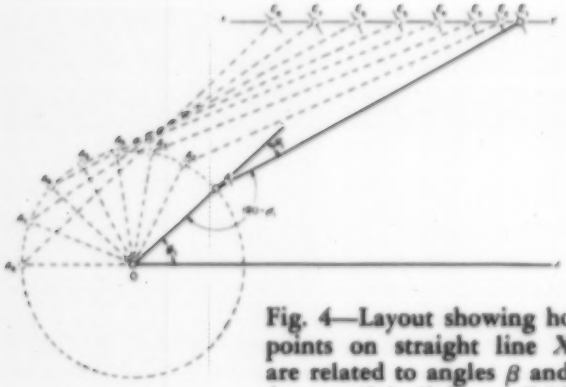


Fig. 4—Layout showing how points on straight line XY are related to angles β and ϕ for partial linkage $EAOZ$

The transparency, *Fig.* 5, is then tried over the curves in the atlas until a good fit is obtained. In the fitting operation, the axes of the overlay curve must at all times be parallel to the respective axes of the curves in the atlas. When a fit has been obtained, the dimensions of the required four-bar linkage can be determined from the key of link ratios on the page of the atlas. However, before the complete mechanism can be laid out, certain angular relationships must be adjusted.

The amount the β-axis of the overlay is shifted to obtain a fit is the angle (α) through which link OC must be rotated—from OZ to OK, *Fig.* 6.

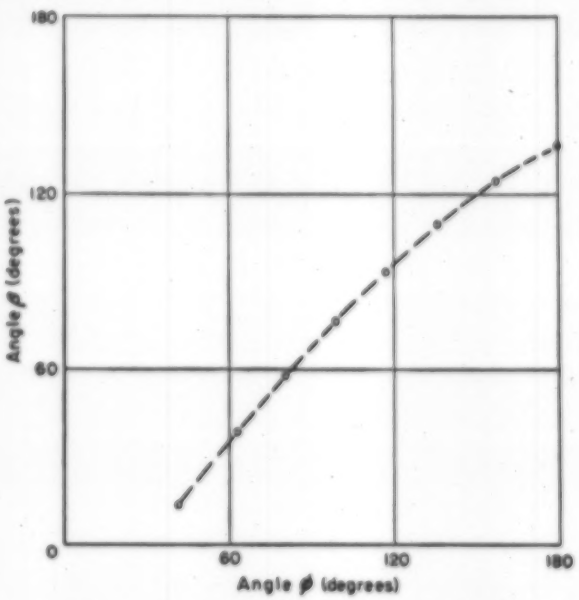


Fig. 5—Overlay of β versus ϕ required of linkage to produce straight-line motion

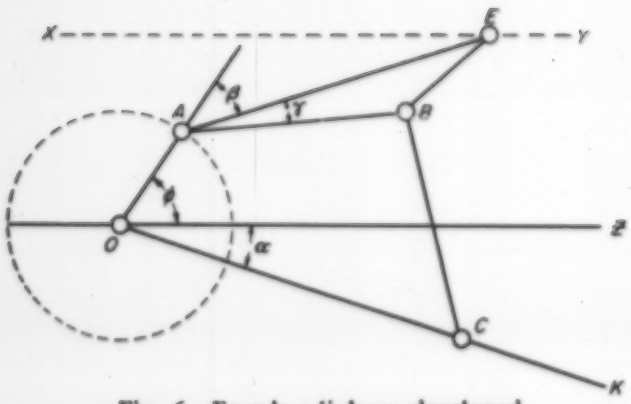


Fig. 6—Four-bar linkage developed from atlas and transparent overlay

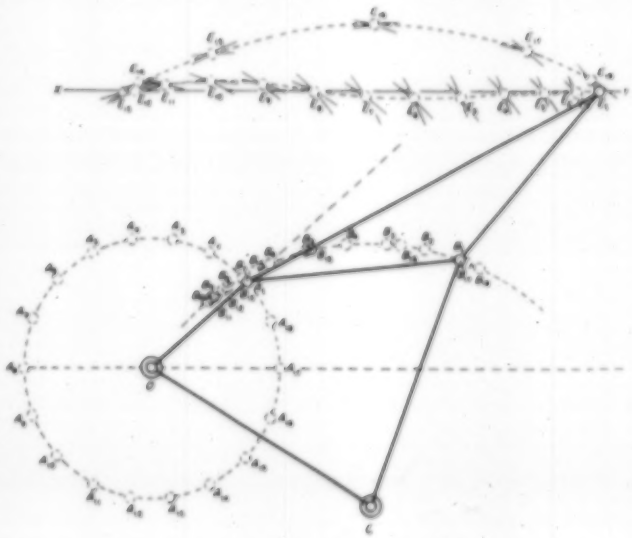
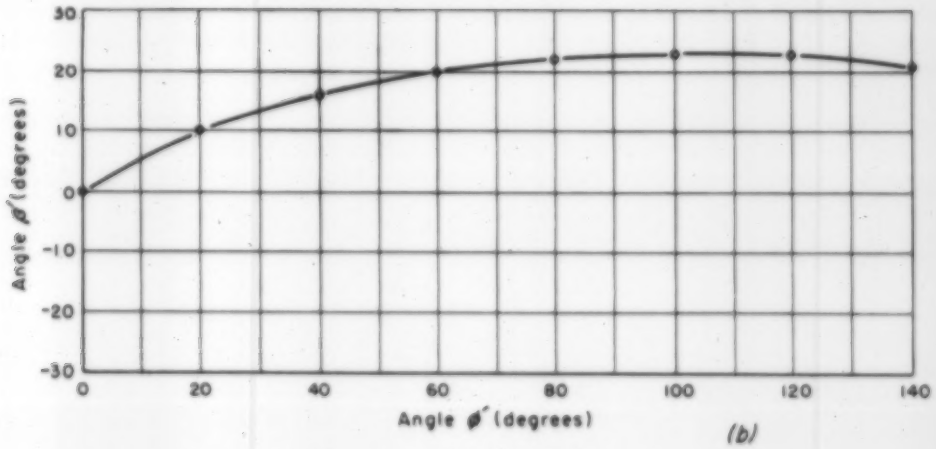


Fig. 7—Layout showing actual motion produced by linkage of *Fig.* 6



(a)

φ′	β′
0	0
20	10
40	16
60	20
80	22
100	23
120	23
140	21

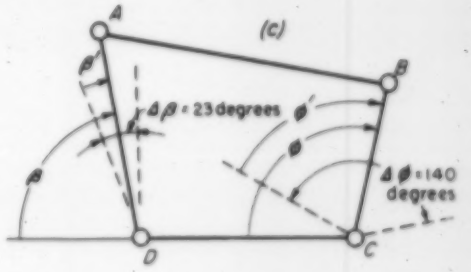


Fig. 8—Three stages in the design of a linkage for producing a prescribed relationship between β' and ϕ'. From tabulated data, *a*, tracing paper overlay, *b*, was plotted and used to find a fit in the atlas, *Fig.* 2. Atlas key of link ratios permitted determination of final dimensions, *c*

The layout of the linkage can then be made. Choose a value for ϕ and lay out OA making an angle $\phi + \alpha$ with OK. Link AE may then be laid off at the corresponding angle β. The other two pivots B and C of the four-bar linkage may then be located by use of the data from the atlas key. The angle γ is the angle which the ϕ-axis of the overlay is moved relative to the axis of the atlas. The coupler triangle can then be completed by joining E and B.

The path of E for the linkage design chosen should be checked to determine if it is satisfactory. The path traveled by point E on the linkage designed in this example is illustrated in *Fig.* 7.

A fit may be found to fall between two β versus ϕ curves. Then, an approximation or interpolation can be made. The linkage so obtained should be laid out to determine if the path produced is satisfactory.

Designing Input-Output Functions: Suppose some functional relationship is to be generated by a mechanical linkage. The atlas method is applicable whether the parameters are linear or angular. If one of the parameters is linear and the other is angular, then a slider crank may be used in series with the four-bar linkage.

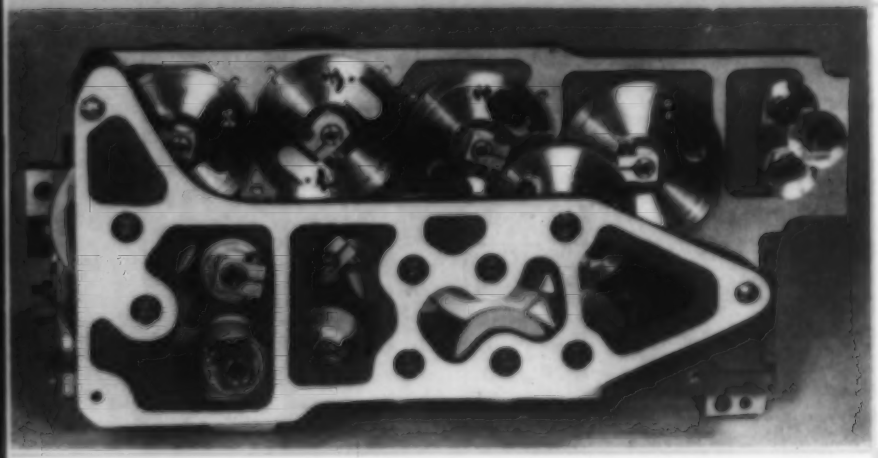
The onus of generation of the function can be divided approximately equally between the slider crank and the four-bar linkage. Also the slider crank alone can be used to convert linear motion to angular motion and the four-bar linkage can be employed to generate the function. Or finally, the slider crank can generate the function as well as convert the variable; the four-bar linkage would apply a correction to the output parameter.

For any of the techniques, the desired β versus ϕ relationship can be plotted for the range of the variable required and for a chosen range of the input parameter β. The curve can be plotted on a transparent overlay to the same scale that the curves in the atlas are plotted. A fit would be obtained in a way similar to that previously described, and the dimensions of the four-bar linkage determined from the atlas key.

A set of data chosen at random is tabulated in *Fig.* 8 for the chosen ranges, $\Delta\phi = 140$ degrees and $\Delta\beta = 23$ degrees. The graph in *Fig.* 8 is a plot of these data drawn to the same scale as that in the atlas. A reasonable fit for this curve was obtained on one of the atlas pages shown in *Fig.* 2. Link ratios are $b/a = 1$, $c/a = 5/6$, $d/a = 4/6$ and ϕ ranges from 159 degrees to 299 degrees.

Conclusion: The function generator described in this article offers an advantage for many situations in that it produces a Cartesian co-ordinate plot of the variables.

Once constructed, the generator can be used to develop curves and atlas sheets in endless number. Perhaps the most practical approach, however, is to prepare atlas sheets in the known or suspected region of link ratios for the job at hand. With each sheet indexed by link ratios, as already outlined, it fits into place in the atlas. As the process continues, the gaps in the atlas are filled in and the range of ratios is extended to include all likely or practicable requirements.



Precision

By G. W. Michalec*
Staff Member
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SOURCES of backlash were reviewed and the integration of backlash throughout the gear train was analyzed in the first article of this series. Various methods for backlash control and elimination will be discussed in this article. Also a numerical example will be presented to show how backlash calculations are made.

Undesirable effects of backlash, particularly in the instrumentation, automatic control and computation fields, have led to considerable effort toward its elimination and control. To make perfect gears is impossible, and the cost of high precision gears may often be prohibitive. Therefore, special design, fabrication, and assembly techniques have been developed to allow the use of imperfect gears and associated parts without the consequence of excessive backlash. Some of these special methods are:

1. Adjustable centers
2. Antibacklash spring-loaded gears
3. Antibacklash gear trains
   a. Multiplicity of antibacklash gear meshes
   b. Auxiliary antibacklash gear train
   c. Auxiliary torque motors
   d. Hairsprings
   e. Series meshing of split gears and one antibacklash gear
4. Fixed split gears
5. Selective assembly
6. Special boring templates and gear sizes
7. Tapered gears
8. Worm mesh backlash reduction
   a. Variable lead worms
   b. Hinged spring-loaded worms
9. Run-in gears

Adjustable centers can be used to decrease backlash in assembly by varying the gear center distance. Feasibility of this procedure depends upon the application. Shafts hung between bearings in separated housings are difficult to adjust because of the need for maintaining parallelism. However, where the gears are overhung, either eccentric bearing bushings or oversized bearing housing holes can be used for adjustment, as shown in *Fig.* 9. A further variation would be a gear mounted on an adjustable arm, such as used in the change gear boxes of lathes and gear-generating machines.

This backlash remedy is most advantageous when only the last mesh of a train is to be adjusted, which is often the case since in a reduction train the last mesh has the most effect on total backlash. Obviously, adjustable centers for a series of gear meshes is cumbersome because of the interrelation of each shaft pair.

Adjustable centers are sometimes utilized in the interconnection of subassembly units by means of gearing. The relative positions of subassemblies are determined by adjustment until backlash requirements are achieved and then the units are made fast.

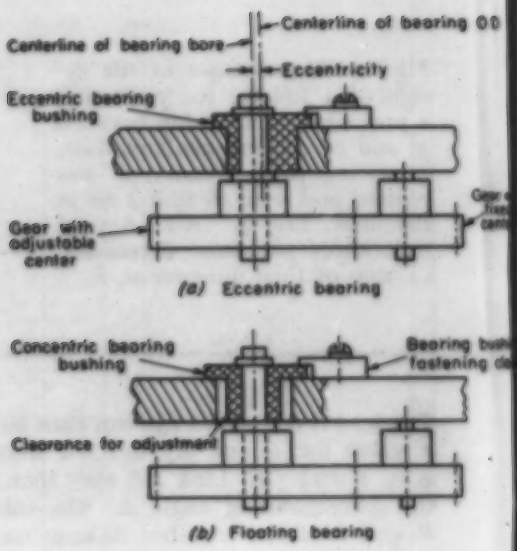

Fig. 9—Two types of adjustable gear-center designs

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Gearing

Part 2 — Antibacklash Devices and Backlash Calculation

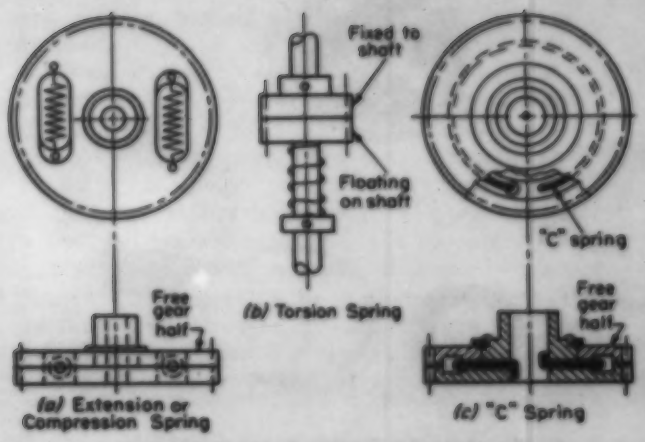


Fig. 10—Three types of spring-loaded antibacklash gears

Adjustable gear meshes increase assembly cost and make field maintenance more difficult. However, they do allow more liberal tolerances on gear center locations and gear size, which partially make up for the increased assembly cost.

There are several distinct disadvantages in using adjustable centers. First they require skilled assemblers, for adjustments are in the order of 0.0005 to 0.001-inch increments. Second, adjustable centers are subject to misadjustment, and in the field there is no assurance of a comparable quality of readjustment to that originally used in assembly. Third, at best, adjustment can take out all backlash except those components due to eccentricities. The goal is zero backlash for the tightest point of mesh, and for other positions backlash will remain.

Antibacklash gears, also known as spring-loaded or scissor type, have the unique advantage of eliminating all backlash when properly applied. They are usually of the design shown in *Fig.* 10, although the method of designing the spring loading may vary. The variations evolve about "C" type springs or torsion springs. Regardless of the details of the specific design, the antibacklash gear consists essentially of two gear members rotationally free relative to one another, but constrained axially.

Spring loading forces the two gear sections apart sufficiently to completely fill the tooth space of a full faced mating gear. Thus, the spring-loaded gear elements adjust themselves automatically to the required tooth thickness. One of the gear members has a hub and is made fast to the shaft, with the other member free. The free gear acts merely as a loading cam. The accuracy of its tooth profile does not affect the accuracy of transmission of motion, which is only governed by the precision of the fixed gear. Thus, the free gear need not be of high quality, although the closer it resembles the fixed gear, the less motion between them.

For antibacklash gears, spring wind-up must be specified, either as a spring-loading torque or a wind-up of a given number of teeth. Making mesh with spring loading is difficult; therefore, to assist assembly and also to provide an inspection check, the gear members can be loosely pinned at the specified wind-up. Then, after the mesh is made, the pin is removed. This method provides the inspection check that the pin holes must be aligned.

Various types of small fine-pitch antibacklash gear assemblies and their constituent parts are shown in *Figs.* 11 through 14. Advantages of using spring-loaded antibacklash gears are:

1. Tolerances on center distance and gear size

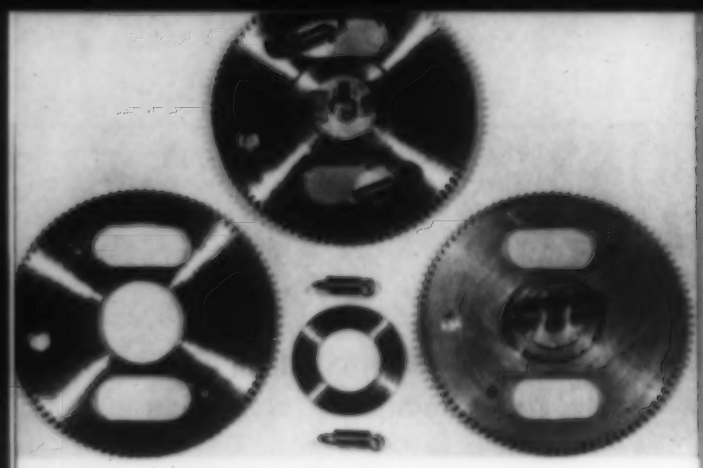


Fig. 11—Spring-loaded antibacklash gear using extension type springs

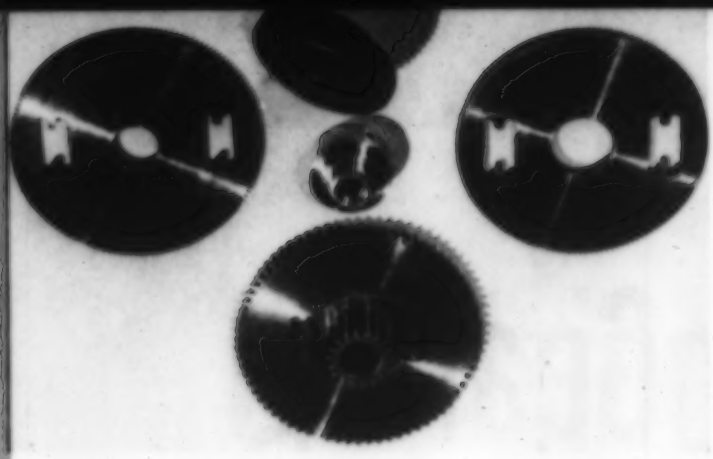


Fig. 12—Spring-loaded gears employing compression springs

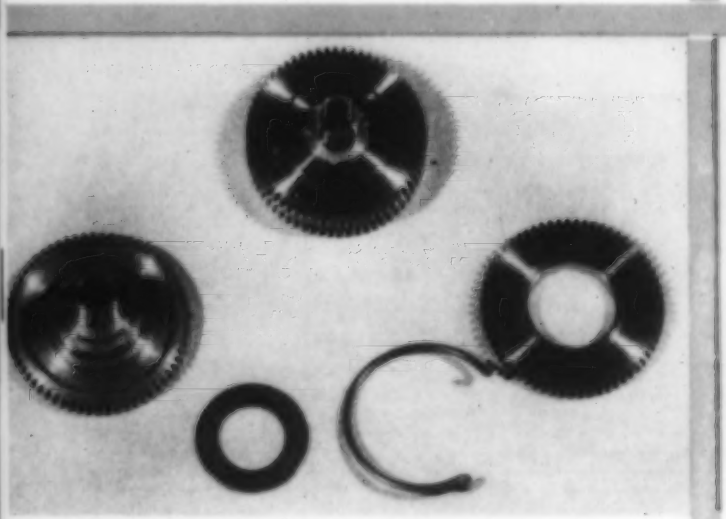


Fig. 13—Antibacklash gear utilizing a "C" type spring. Gear is 64 pitch, 1-inch pitch diameter

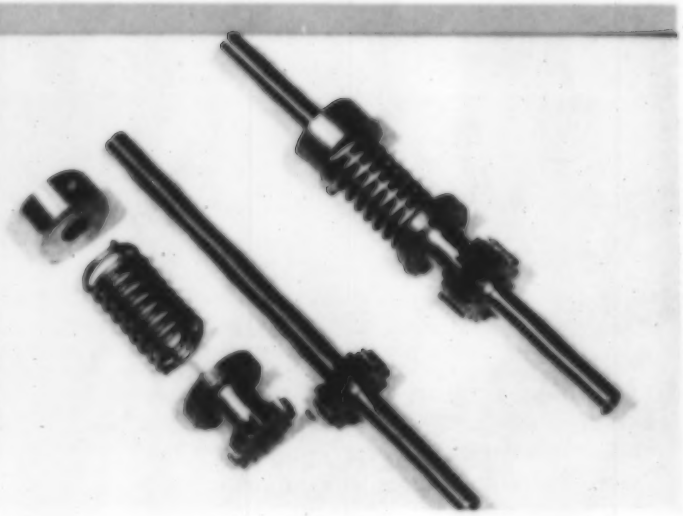


Fig. 14—Torsion type antibacklash pinion of 48 pitch, 14 teeth

need not be close since backlash due to these variations will be eliminated. Further, if accuracy of transmission is no concern, the total composite error, bore clearance, bearing runouts, etc., can have wide tolerances.

2. All backlash is continually eliminated.
3. Differential expansion effects on backlash are automatically corrected.

Main disadvantages of these gears are:

1. Spring loading must be at least equal to the maximum load to be transmitted, which is not always easy to predict. Thus, this type of gear is limited to relatively low torque.
2. Gears and bearings are always loaded to a maximum, which increases friction losses.
3. Much reliance is placed upon the assemblyman since these gears are subject to malfunction if not properly spring loaded.
4. The double gear element requires the pinion to have a comparably longer face. Also, the weight and space required by the free gear can become a consideration in small, compact instrument designs.

Antibacklash gear trains are considered when it is necessary to eliminate or reduce the backlash of more than just one specific mesh. Several alternative methods can be used:

MULTIPLICITY OF ANTIBACKLASH GEAR MESHES is possible, consisting of a simple application of antibacklash gears; that is, one gear of as many pairs as necessary is made antibacklash. Thus, backlash is only eliminated in those meshes which are composed with spring-loaded gears. However, since only the heavily contributing backlash meshes are made antibacklash, this method allows for efficient use of antibacklash gears.

AUXILIARY ANTIBACKLASH GEAR TRAIN can be used to remove the train backlash by winding up the gears by means of a second gear train, as shown in *Fig.* 15. In effect, there are two gear trains: the functional or desired train, and the auxiliary antibacklash train. The input shaft has two identical gears or one wide gear. The output shaft has a fixed gear and a spring coupled gear which is part of the antibacklash train.

Between the input and output shafts, the functional gear train is duplicated in the antibacklash train. The duplication need not be exact, gear for gear, but the overall velocity ratio must be the same. The spring coupled gear on the output shaft is loaded to exert the desired torque when meshed, thus loading all meshes of the entire train.

This method has the advantage of removing a great deal of backlash with one spring. However, in most cases this is unnecessary since in high velocity trains the last one or two meshes are the only critical ones. Also there is the further disadvantage of requiring twice as many parts and considerably more space.

AUXILIARY TORQUE MOTOR is used to remove much of the backlash from a series of stages in a gear train by employing a small auxiliary torque motor which is constantly energized in the same direction of rotation. This auxiliary motor causes the gear meshes to be constantly loaded in one direction and thus eliminates backlash. However, to avoid having the motor drive the train backward, this technique is limited to applications where there is considerable gear reduction, so that the torque motor faces into a friction load magnified from the higher speed stages. Thus, only the backlash of the last few stages is eliminated, but this is very satisfactory since they are the stages contributing the bulk of the gear train backlash. Also, because this method is limited to high-velocity gear trains, the added load of the auxiliary torque motor is negligible for any prime mover located at the high-speed end of the gear train.

A gear train utilizing a torque motor is illustrated schematically in *Fig.* 16.

This method of backlash elimination is most suitable for gear trains which have many meshes at the low-speed end. It has the further outstanding advantage that the output has no restriction upon the number of turns it can make. However, this method does require the expense of an extra motor plus the requirement of installation space and power consumption. Further, it should be realized that this means of backlash elimination is not applicable to cases where the loads are high, for then a small auxiliary motor would not fulfill the function and use of a larger unit would be poor design, besides causing considerably greater gear train loads.

HAIRSPRINGS can be used to replace the torque motor with a spring force for gear trains having limited rotation on the low-speed end, such as the drive of a potentiometer or a dial. Usually the spring is of the torsion variety, having one end fixed and the other fastened to a gear of the train. Prior to making the mesh the spring is wound an appropriate number of turns. Then, in mesh the spring will force the gear against its mate, thus eliminating backlash. If there is additional gearing beyond the hairspring mesh, its

Fig. 15—Schematic showing how a second gear train eliminates backlash by winding up the gears of the functional train by spring loading

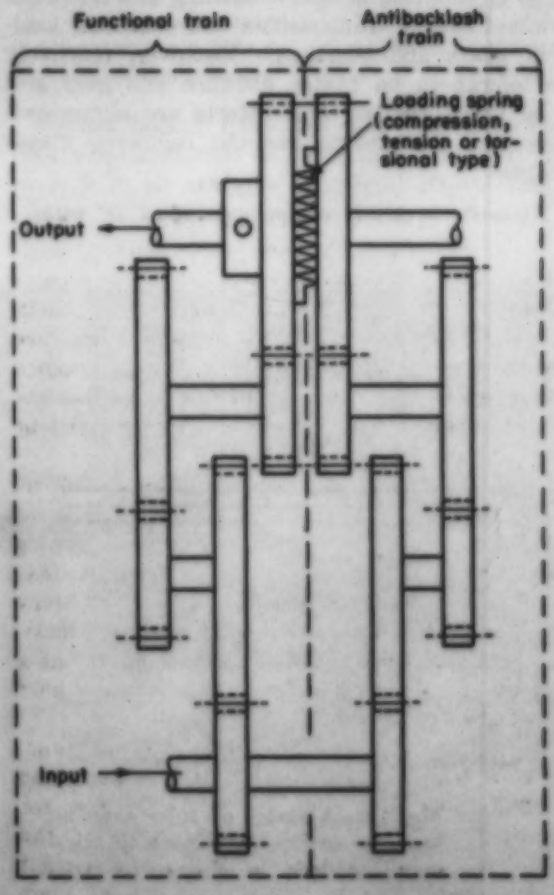
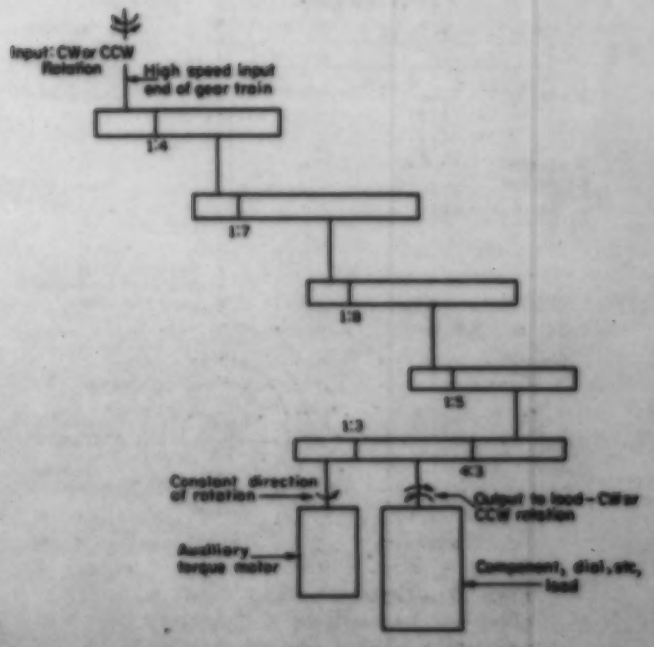


Fig. 16—Gear train utilizing a torque motor to eliminate backlash



backlash will also be eliminated to the point in the gear train where the spring force cannot overcome friction. A schematic illustration is shown in *Fig.* 17.

Note that in the use of an antibacklash spring, the spring force is merely used for loading the gears to one side of each mesh, just as in the case of the torque motor. The gear train will always remain loaded in this direction provided the driven load never exceeds the spring torque. This implies limitation to light duty and small instrument applications, resulting in the spring being of small design, and hence often referred to as a hairspring.

An important limitation of its application, besides low torque transmission, is the restriction of motion since a torsion (or other type) spring can only make a finite number of turns, the exact number depending upon the design. Also, the design of the spring should favor a low spring rate so as to diminish the variation of spring torque with deflection.

In some special cases hairsprings are used where the load exceeds the spring force, but where the drive is only unidirectional. In such applications the function of the hairspring is limited to the elimination of the backlash of one mesh only.

SERIES OF SPLIT GEARS AND ONE ANTIBACKLASH GEAR is a variation of the form and application of the antibacklash gear in the case of certain other special gear trains. An example is when one gear is to drive two or more gears without backlash, which is fairly common in computers where one gear positions several component shafts. In the example shown in *Fig.* 18, the series of gears is spring loaded by one antibacklash gear at the end of the train and two additional double gears, identical to antibacklash gears except they have no loading springs. Thus, the end gear loads the entire train.

Two precautions must be observed. The spring loading must be ample to drive the entire load and each member of the double gears must mesh with only its appropriate mates. This latter precaution can be readily observed by spacing the gear members apart. This type of train design has several advantages when compared to the previous alternatives. First, it involves fewer parts and much less space. Second, the double gears are standard antibacklash gears but without springs; thus common parts are used.

Fixed split gears constitute a variation of antibacklash gear design for applications of high torque where the spring loading would become unreliable. This method uses the fixed and free gear elements without springs, but with the addition of locking screws. In this procedure, the two gear members are adjusted in mesh to properly fill the tooth space and then clamped together securely by means of locking screws. In some very high torque applications where reliance on the friction locking action of the screws is dubious, the gears are either doweled or riveted together.

In the use of this design, caution must be taken to be certain the gears are locked at their tightest point of mesh. If this is not done, there will be interference when the tightest point of mesh comes into contact.

The main advantage of this type of antibacklash gear is elimination of spring loading and its faults of limited torque transmission and continual loading of gears and bearings. Moreover, relatively wide tolerances on center distance and gear size can be used because their effects are eliminated.

However, this design has the following disadvantages:

1. At best, backlash components fixed in value

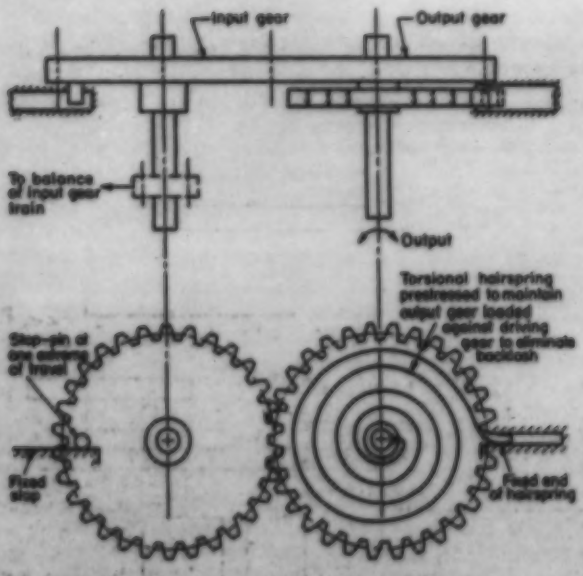

Input gear
Output gear
To balance of input gear train
Output
Torsional hairspring prestressed to maintain output gear loaded against driving gear to eliminate backlash
Fixed stop
Fixed end of hairspring

Fig. 17—Torsion spring used to eliminate backlash in a light-duty gear train having limited rotation

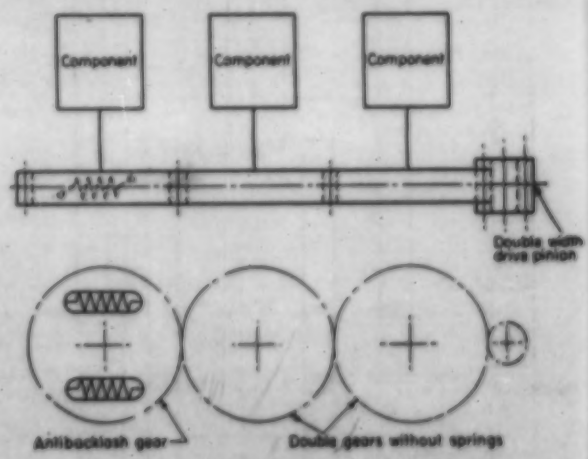


Fig. 18—A series of split gears using one antibacklash gear to eliminate backlash in the entire train

can be eliminated. Backlash components variable with rotation cannot be removed.
2. Assembly is involved and expensive since it requires a skilled mechanic upon whom much reliance is placed in properly adjusting and locking the gears.
3. Again, the double gear requires a wide-faced pinion resulting in a larger assembly.
4. These gears are not interchangeable since each gear assembly is set up for a specific center distance. Also, for a given pair of centers, if the parameters affecting backlash components variable with rotation are altered, there may be a resultant interference since the split gear is set up for an original different combination of conditions.

Selective assembly, as a method of eliminating backlash, can be used where production quantities are great enough to provide selectivity for each parameter affecting backlash. The various parts comprising the assembly are inspected and segregated at inspection. Later, in assembly, the parts are selected to provide the desired backlash condition.

Advantages of this method are:

1. Gears are simple in design. They are half the width and weigh less than antibacklash gears.
2. There is no limit in torque transmission except limiting tooth strength.

Disadvantages are:

1. Large production is required to provide a selection.
2. Inspection and assembly costs are increased.
3. Backlash components variable with rotation cannot be eliminated.
4. Interchangeability is lost and field replacement difficulties increase.

Special boring templates and gear sizes constitute a method that is not commonly used. However, it is an example of special efforts that can be made to combat backlash.

In this procedure, the drill template or jig for the boring of gear centers is made and tried on a work piece. Then, the actual gear center distances, as measured from the sample work piece, are used for calculating the exact size of the gears. For each gear mesh, one gear is produced and then inspected so as to determine the size of the mating gear for minimum backlash of the mesh. The drill template can have relatively open tolerances on center distance, but the jig should have a high degree of reproducibility in each work piece. The only particular advantage of this method is the elimination of most of the backlash due to center distance variation. However, this is offset by the following disadvantages:

1. Only backlash due to center distance variation is eliminated.
2. The gears are of special size, which eliminates interchangeability between production lots from different drill templates.
3. Limited production is obtained due to drill bushing wear.

Tapered or conical gears are not used to any appreciable extent but offer considerable possibilities. Perhaps they would find greater use if their principles were more widely understood.

Normally, spur and helical involute gears have tooth elements parallel to the pitch plane, *Fig.* 19*a*. However, if the gear were generated by a shaping process whereby the cutter reciprocates along an axis inclined to the gear blank axis, the result would be a gear such as shown in *Fig.* 19*b*. This could also be done on a hobbing machine by having a cam or linkage alter the distance between the hob and work as the tool is fed across the gear blank.

Across the length of the pitch cylinder, this gear has variable tooth thickness, from a minimum at one end to a maximum at the other. In effect,

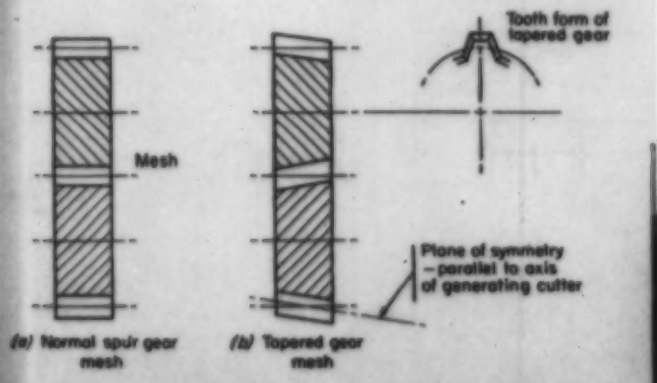
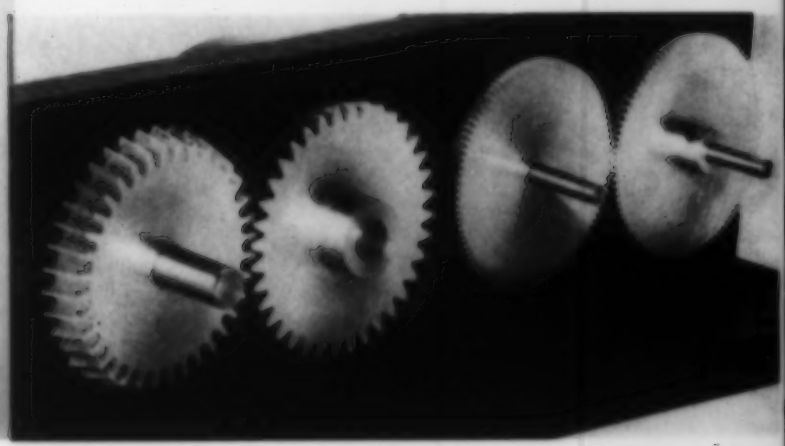

Tooth form of tapered gear
Mesh
Plane of symmetry – parallel to axis of generating cutter
(a) Normal spur gear mesh
(b) Tapered gear mesh

Fig. 19—Comparison of normal spur gear mesh with mesh of tapered gears which can be adjusted axially to reduce backlash

Fig. 20—Experimental tapered gears mounted on test bracket. Pair at left is 24 diametral pitch; pair at right is 64 diametral pitch



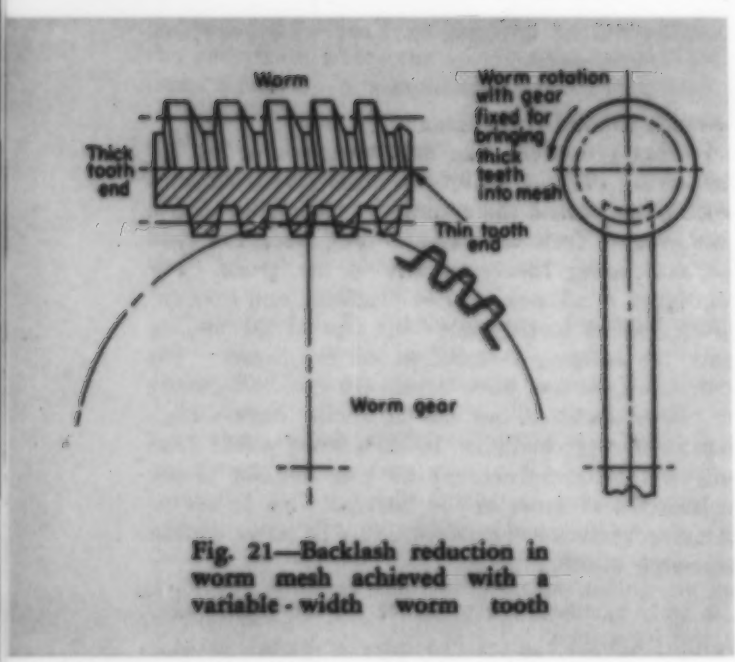


Fig. 21—Backlash reduction in worm mesh achieved with a variable-width worm tooth

it is a modified gear, but one composed of infinite degrees of modification between two limits. If two such gears are meshed, *Fig.* 19*b*, they are conjugate, with full line contact. Since they are of involute form, their center distance can be varied with no ill effect upon gear action. As can be seen from *Fig.* 19*b*, backlash can be conveniently adjusted by relative axial movement of the gears. Experimental pairs are shown in *Fig.* 20.

Advantages of this method are:

1. All backlash except components variable with rotation can be eliminated.
2. The fine adjustment to eliminate backlash is done with a noncritical (magnified) axial movement.
3. Torque transmission is only limited by tooth strength.
4. Complete interchangeability.

Disadvantages are:

1. Production of these gears requires modification of standard generating machines with special attachments.
2. Inspection of these gears requires matched master gears or master racks.
3. The feature of axial adjustment places another demand on the design.

Worm mesh backlash reduction is a difficult problem. Adjustable centers have been used with some success. However, another solution is a worm with variable lead; a variable-width worm tooth results across the axial length of the worm. In assembly, mesh with the worm gear is made by axially sliding the worm until the backlash of the mesh is absorbed. Then the worm is fixed, *Fig.* 21, by fixing the worm gear and screwing in the worm. At best, this method will only eliminate nonvariable components of backlash.

Chief disadvantages are:

1. Requires an unusual worm made with special attachments on a thread milling machine.
2. Actually, backlash along the line of action will vary because of the variable worm lead.
3. If mesh is not set up and checked for the beginning of gear action, there might be binding.

Another method for eliminating worm mesh backlash is to pivot one worm shaft bearing about the other bearing which is hinged and thus force the worm into intimate contact with the worm gear by means of a loading spring. This arrangement is shown schematically in *Fig.* 22.

This method has the usual disadvantages of spring loading and, in particular for this type of gearing, continual spring loading is undesirable because of the large amount of sliding and rubbing in a worm mesh. Fortunately, backlash due to wear will be automatically eliminated by the spring loading. A further serious disadvantage is that the worm shaft bearings must be movable, which complicates the design.

Run-in of gears is not recommended. The sometimes common notion that backlash can be minimized by making interference gear center distances

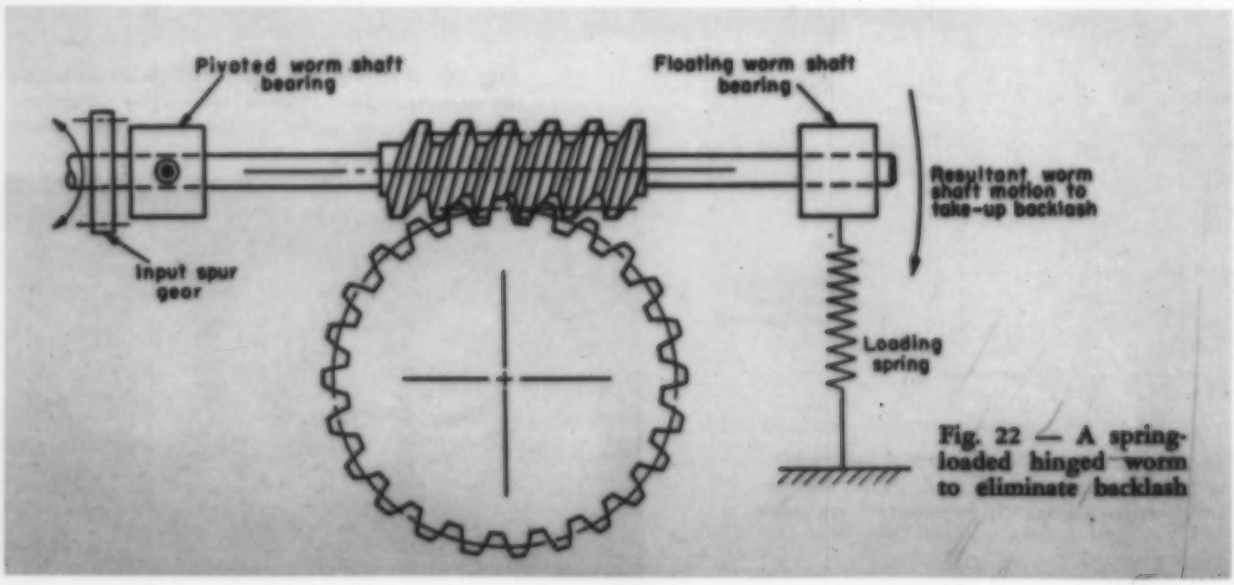

Pivoted worm shaft bearing
Floating worm shaft bearing
Resultant worm shaft motion to take-up backlash
Input spur gear
Loading spring

Fig. 22 — A spring-loaded hinged worm to eliminate backlash

and then running in the gears is basically wrong. Involute gears will not preserve their profile under abrasive wear. This condition is obvious because the rate of cam sliding varies from zero at the pitch line to maximum at the base cylinders. Thus, wear will vary across the profile, which will result in loss of involute shape and conjugate action.

Further disadvantages are that throughout a gear train, the velocity ratio varies with each mesh. Thus the rates of wear are radically different, requiring separate running-in set-ups. Also, abrasive compounds are dangerous in precision mechanisms, and cannot easily be completely removed.

Therefore, this method should never be considered.

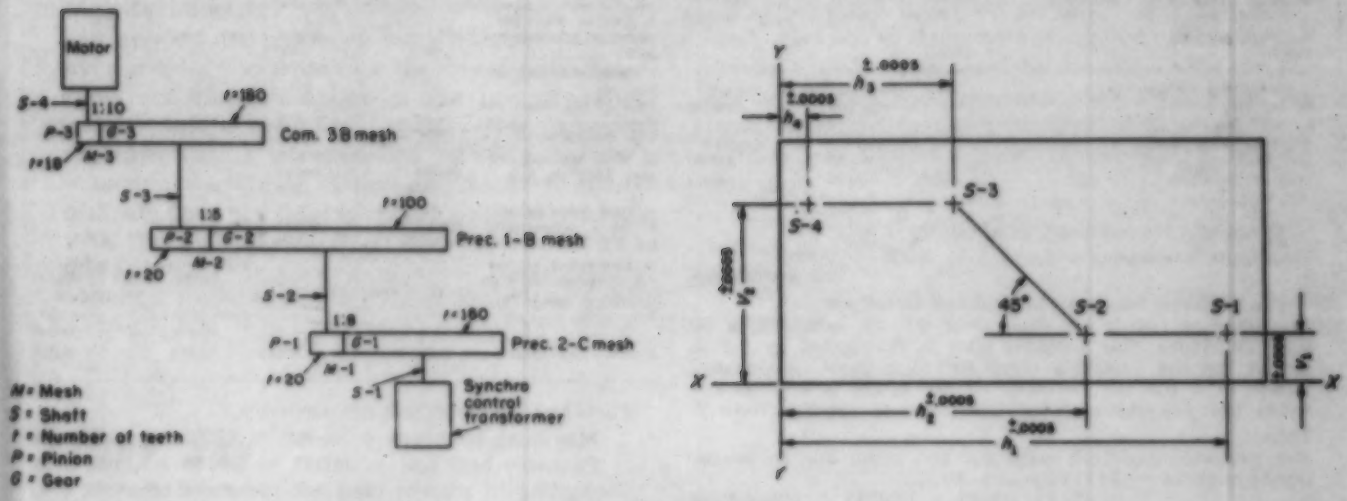
An evaluation of methods to eliminate or reduce backlash, in terms of application to the instrument and computer field in general can be presented briefly.

Antibacklash gears are very commonly used in low-torque applications. Adjustable centers are also commonly used, particularly where there are appreciable loads. Selective assembly is only resorted to in extreme cases where production is sufficiently high to make it feasible. Tapered gears have vast potentialities, but due to lack of generating equipment, must still remain relatively unexplored. The balance of the methods are special cases and their employment would require detailed knowledge of the applications. As has been indicated, run-in of gears is not even to be considered.

Calculating Maximum and Probable Backlash

Regardless of the detail design of the gear train, it will have some amount of backlash, unless it is designed exclusively with antibacklash gears such as just reviewed. Therefore, the ability to calculate maximum and expected probable backlash from the design drawings is of considerable value. The procedures for doing this have been

Fig. 23—Gear train details for example demonstrating how to calculate maximum and probable backlash



DESIGN CONDITIONS

1. Gears on motor and synchro are mounted on their shaft ends. All other gears mounted in ball bearings class ABEC-5; radial play 0.0003 to 0.0006-inch.
2. All gears: 48 pitch, 20-degree pressure angle; number of teeth and AGMA gear class as noted on schematic. The AGMA specified backlash per pair is to be equally divided between the two gears of the pair.
3. All gears pinned to shafts except G-1 and P-3 which are clamped. Recommended fits of Table 5 are to be assumed.
4. Shafts S-2 and S-3 are 4 inches long, centerless ground stock and can be considered accurate to 0.0001-inch total indicator reading per inch. The bearings are at the shaft ends and the gears are located approximately 1 inch from the bearings.
5. The gear centers are so co-ordinate dimensioned that the minimum center distance is nominal. The tolerance on co-ordinates is ±0.0005-inch. Orientation of center lines relative to co-ordinate axes X-X and Y-Y is shown by accompanying sketch.
6. Both the synchro and motor mounting diameters are 1.0000 + 0.0000 − 0.0005-inch and fit into housing bores 1.0003 + 0.0007 − 0.0000. Also both shaft ends run true within 0.001-inch total indicator reading, and have a radial play of 0.0005-inch maximum.

Table 8—Example Calculations

Mesh 1—Groups A and B

Backlash Components	Gear G-1 Max. Backlash	Gear G-1 Prob. Fact.	Gear G-1 Prob. Backlash	Pinion P-1 Max. Backlash	Pinion P-1 Prob. Fact.	Pinion P-1 Prob. Backlash
1. Center distance variation (for a meshed pair)	(.002) .0014	½	(.001) .0007			
2. Gear size and tolerance: Intentional size reduction	.0005		.0005	.0005		.0005
Size tolerance	.0005	½	.00025	.0005	½	.00025
3. Clearance of synchro in mounting hole	(.00075) .00055	½	(.00037) .00027			
4. Synchro shaft radial play	(.00025) .00018	½	(.00012) .00009			
5. Radial play of ball bearing on *S*-2				(.0003) .0002	2/3	(.0002) .00014
6. Ball bearing outer race eccentricity (on *S*-2)				(.0001) .00007	1	(.0001) .00007
Sum of backlash	.0031		.0018	.00127		.00095

Therefore, backlash at mesh 1 for components of Groups A and B only:

Maximum backlash = .0031 + .00127 = .0044-inch

Probable backlash = .0018 + .00095 = .00276-inch

Mesh 1—Group C

Backlash Components	Gear G-1 Max. Backlash	Gear G-1 Prob. Fact.	Gear G-1 Prob. Backlash	Pinion P-1 Max. Backlash	Pinion P-1 Prob. Fact.	Pinion P-1 Prob. Backlash
1. Total composite error	(.0005) .00036	.8	(.0004) .00029	(.0005) .00036	.8	(.0004) .00029
2. Radial clearance between gear bore and shaft	(.00025) .00018	¾	(.00019) .00014	(.00025) .00018	¾	(.00019) .00014
3. Synchro shaft runout	(.0005) .00035	.7	(.00035) .00025			
4. Shaft *S*-2 runout at position of *P*-1				(.00005) .000036	1	(.00005) .000036
5. Ball bearing inner race eccentricity (on *S*-2)				(.0001) .00007	1	(.0001) .00007
Sum of backlash	.0009		.00068	.00065		.00054

Therefore, for components of Group C only:

Maximum backlash for mesh 1 = .0009 + .00065 = .00155-inch

The probable backlash is obtained as follows:

The phasing factor for each error will be assumed to be 0.7. Therefore, the probable sum is multiplied by 0.7 to obtain the net probable error for each gear. A phasing factor of 1 for the meshing of the gears is applied because the velocity ratio of the mesh is greater than 2. Thus,

Net probable backlash error for the mesh due to eccentricity sources = $.7(1)(E_{G(p)} + E_{p(p)})$

= .7(1)(.00068 + .00054) = .00085-inch

This is a maximum backlash value since with rotation its value will undergo changes between the values ± .00085-inch.

The grand total backlash of mesh 1 for all three groups of sources will be

Maximum backlash = B_{max} = .0044 + .00155 = .006-inch

Probable backlash = B_{prob} = .00275 + .00085 = .0036-inch

Converting to angular backlash measured at the pinion shaft *S*-2,

Maximum backlash = $.006/r_{P-1} = .006/.208$

= .029-radian = 1.65 degrees

Probable backlash = .0036/.208

= .017-radian = .99 degree

In a similar manner, the backlashes of meshes 2 and 3 will be determined. However, the backlash errors due to Group C will be omitted since the individual sources of this group are mostly negligible and, besides, for higher-speed shafts such as *S*-2 and *S*-3 the probable average will be their algebraic mean which is zero.

Mesh 2—Groups A and B

Backlash Components	Gear G-2 Max. Backlash	Gear G-2 Prob. Fact.	Gear G-2 Prob. Backlash	Pinion P-2 Max. Backlash	Pinion P-2 Prob. Fact.	Pinion P-2 Prob. Backlash
1. Center distance variation (for meshed pair)	(.0028) .002	½	(.0014) .001			
2. Gear size and tolerance: Intentional size reduction	.001		.001	.001		.001
Size tolerance	.001	½	.0005	.001	½	.0005
3. Ball bearing radial play	(.0003) .0002	2/3	(.0002) .00014	(.0003) .0002	2/3	(.0002) .00014
4. Ball bearing outer race eccentricity	(.0001) .00007	1	(.0001) .00007	(.0001) .00007	1	(.0001) .00007
Sum of backlash	.00427		.00271	.00227		.00171

Therefore, the backlash for mesh 2 is:

Maximum backlash = .00427 + .00227 = .0065-inch

Probable backlash = .00271 + .00171 = .0044-inch

Converting to angular backlash measured at pinion on shaft *S*-3,

Maximum backlash = $.0065/r_{P-2} = .0065/.208$

= .031-radian = 1.8 degrees

Probable backlash = .0044/.208

= .021-radian = 1.2 degrees

Mesh 3—Groups A and B

Backlash Components	Gear G-3 Max. Backlash	Gear G-3 Prob. Fact.	Gear G-3 Prob. Backlash	Pinion P-3 Max. Backlash	Pinion P-3 Prob. Fact.	Pinion P-3 Prob. Backlash
1. Center distance variation (for meshed pair)	(.002) .0014	½	(.001) .0007			
2. Gear size and tolerance: Intentional size reduction	.001		.001	.001		.001
Size tolerance	.001	½	.0005	.001	½	.0005
3. Ball bearing radial play on *S*-3	(.0003) .0002	2/3	(.0002) .00014			
4. Ball bearing outer race eccentricity on *S*-3	(.0001) .00007	1	(.0001) .00007			
5. Clearance of motor in mounting hole				(.00075) .00055	½	(.00037) .00027
6. Motor shaft radial play				(.00025) .00018	½	(.00012) .00009
Sum of backlash	.00367		.00241	.00273		.00186

Therefore, the backlash for mesh 3 is:

Maximum backlash = .00367 + .00273 = .0064-inch

Probable backlash = .00241 + .00186 = .0043-inch

Converting to angular backlash measured on shaft *S*-4,

Maximum backlash = $.0064/r_{P-3} = .0064/.1875$

= .034-radian = 2 degrees

Probable backlash = .0043/.1875

= .023-radian = 1.3 degrees

The total backlash for the entire gear train measured at the motor shaft will be the sum of backlashes for the three meshes. However, the backlash values for each mesh must be modified by velocity ratio when measured at the motor.

Thus, the total backlash for the gear train measured at the motor shaft (*S*-4) is:

$B_{M-3} + N_1 B_{M-2} + N_2 B_{M-1}$

= 2 + 10 (1.8) + 50 (1.65) = 102 degrees

where N_1 = ratio of mesh 3 and N_2 = ratio of mesh 3 times ratio of mesh 2.

Similarly, the total probable backlash for the gear train measured at the motor shaft is

1.3 + 10 (1.2) + 50 (.99) = 74 degrees

presented in *Part* 1. However, to present a better understanding and appreciation of this analysis an illustrative numerical example will be analyzed.

Assume it is required to determine the maximum and probable backlashes, measured at the motor shaft, for the gear train shown in *Fig.* 23. Design conditions for the problem are also enumerated in *Fig.* 23. *Tables* 1 to 7, *Part* 1, contain data or references necessary for certain of the procedures to follow. The calculations are tabularized in *Table* 8.

For convenience, the various backlash components for each gear and pinion mesh are tabulated. Both maximum and probable values are listed. The backlash component for center distance is for a meshed pair. Its value is arbitrarily listed in the gear column but, of course, is related to both the gear and pinion.

The figures at the upper left and in parentheses are the eccentricity values directly obtainable from the given conditions and data, and are converted to equivalent backlash by use of Equation 1, *Part* 1. Data given as total radial shake, diametral clearance or total indicator reading must be halved in order to obtain eccentricity.

The designations Group A, B, or C refer to the various types of backlash components as defined in *Table* 7, *Part* 1.

Gear center variation, from the information given, is not intentional The only opening is that due to tolerances on location of the gear centers. Therefore, the actual center distance is equal to the nominal center distance plus the total center-distance tolerance.

Note that the value of total tolerance depends upon both the tolerance on the co-ordinate dimensions and the orientation of the line of centers relative to the co-ordinate axes. This point was explained earlier in connection with *Fig.* 2, *Part* 1.

In the case of line of centers parallel to the co-ordinate axes, the total tolerance will be 0.002-inch; with the line of centers at 45 degrees it will be 0.0028-inch.

Since the co-ordinate dimensions have bilateral tolerances, the assumption will be made that the probable center distance is that given by the mean co-ordinate value. Thus, for centers parallel to the axes, the probable opening will be 0.001-inch; and for the one case of 45-degree orientation, the probable opening will be 0.0014-inch.

Gear size variation is composed of the two factors: intentional backlash and size tolerance, both specified by the AGMA class. The value for these quantities is taken from *Table* 2, *Part* 1, including probability factors.

Components variable with rotation are detailed in *Fig.* 23. Probability factors are applied according to *Tables* 2 through 4, *Part* 1. Since these components are usually applied as a total indicator reading, the maximum center distance opening is one-half this value.

In summary, it is evident that meshes adjacent to the motor—that is, high speed shafts—have little effect on the total backlash. However, the meshes on the far end, or low-speed end, contribute much backlash to the system because of the multiplying effect of the velocity ratio. Therefore, often it is not necessary to compute and consider the backlash effects of the remote meshes. In the foregoing example, mesh 3 could have been neglected. The result would have been a 2 per cent error which is well within the accuracy of the method of analysis and computation.

Furthermore, it should be noted that the first mesh adjacent to the synchro (mesh 1) contributes the bulk of the gear train backlash. Therefore, if any antibacklash devices are considered, such as those described in the preceding portions of this article, they would be most effectively applied to this mesh.

Next month in *Part* 3 of this series the inaccuracy or index error of gear trains will be analyzed.

They Say . . .

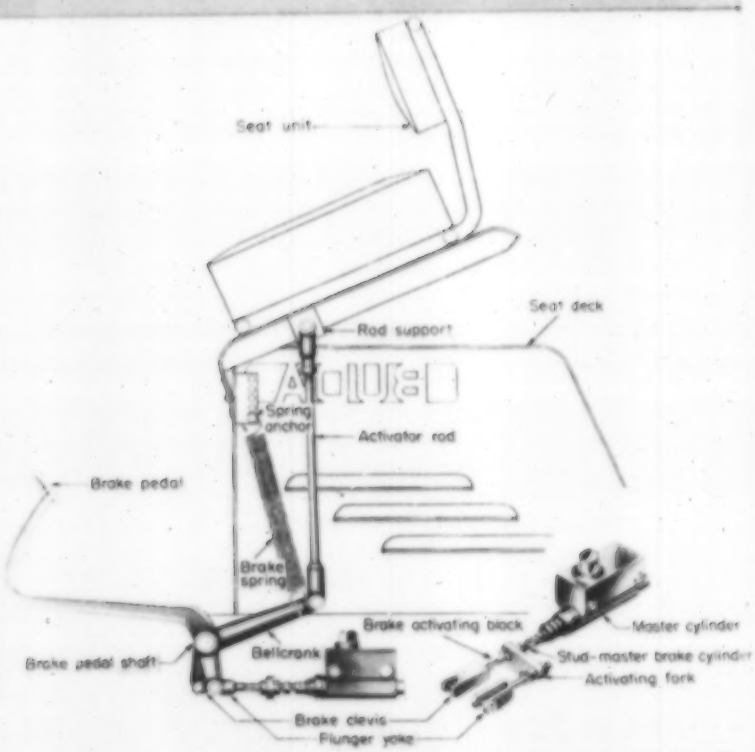
"If American science is to continue to prosper, if it is to continue to attract to it its proper complement of creative and gifted minds, we must everywhere combat the mistaken notion that science and engineering are narrow, provincial and destructive of human values. We must demonstrate instead that science and engineering are great liberalizing, humanizing forces, as well as the greatest intellectual structure achieved by our civilization, and that the spirit and outlook of science have given and continue to give strength and vigor to the character and spirit of the American people." —Dr. James R. Killian Jr., *president, Massachusetts Institute of Technology.*

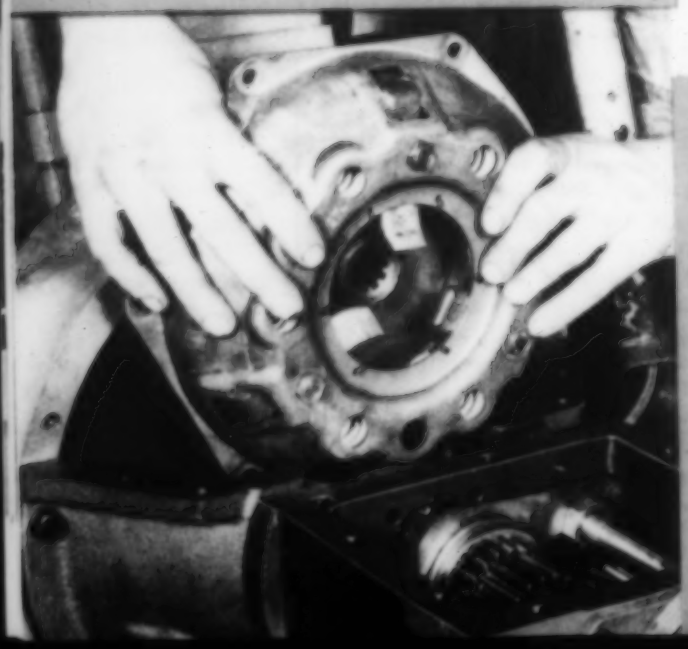
"The basic difference between industrial design and engineering is that industrial designers deal with the *psychological,* while engineers deal with the *physical.* It is of no consequence that both are working with a tangible product. . . The engineer is entrusted with the job of creating a mechanism which will perform a given duty and specifying a method of construction which will permit the article to be manufactured. . . It is the job of the industrial designer, although he is limited by manufacturing processes and the practical problems of production, to create within the minds of people the desire of possession."—J. O. Reincke, *president, Society of Industrial Designers.*

Lift Truck Designed for Safety, Serviceability

A NEW 2000-pound capacity platform truck, the Chore Boy, incorporates interesting design features which make for safer operation and ease of servicing. Powered by a two-cylinder, 13.6-hp, air-cooled engine, the Chore Boy is 97 inches long, 42 inches wide and has a wheelbase of 62 inches. Capacity may be increased to 3500 pounds by using cushion-type, rather than pneumatic, tires. Manufacturer is The Buda Co.

Dead-man brake is actuated by two heavy-duty brake springs which force the operator's seat upward when the operator leaves his seat for any reason. Springs also move a bellcrank and push rod to actuate hydraulic service brakes in the drive wheels. When the seat is forced down by driver's weight, brakes are automatically released. Normal operation of the brake pedal and system is in no way affected by this device.





Quick-change clutch is heavy-duty, dry type. Two-piece clutch housing permits easy removal of upper portion. Transmission design allows retraction of clutch shaft and drive gear which makes removal of clutch pressure plate and disk possible with the transmission in place. Conventionally, the entire transmission would have to be removed in order to change a clutch. Changing time of only 30 minutes is claimed to result from this construction.

Charts speed use of parabolic formula for

COLUMN DESIGN

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EULER'S column formula, which is based on deflection theory, is usually considered the most satisfactory one available for the stress analysis of axially loaded slender columns. However, for short and intermediate length columns, no such panacea exists. Instead, a number of empirical formulas, each with certain limitations, are presently in use.

For example, the so-called *straight-line* formula can indicate stresses for short columns that exceed the yield strength of the material. The *Gordon-Rankine* formula, for large slenderness ratios, can indicate dangerously high allowable stresses, far exceeding the solution by Euler's formula. When a factor of safety is applied to reduce this tendency, the curve is still discontinuous with respect to the Euler curve. The *secant* formula is of relatively complicated form, and requires the use of a factor of equivalent eccentricity for which insufficient experimental data are available.

In addition, as usually given in the literature, these three formulas are applicable to one material only, such as structural steel, etc. To evaluate other materials for a given design requires an entirely separate calculation, provided formulas are available for those materials.

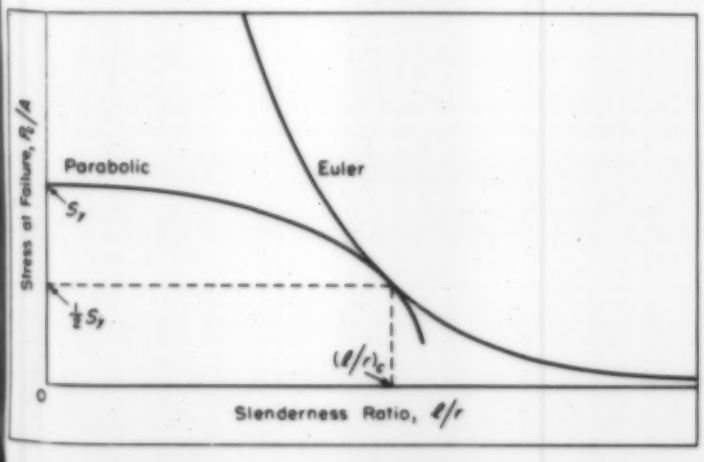
The *parabolic* column formula, first proposed by Prof. J. B. Johnson in 1892, offers several important advantages to the designer:

1. Conforms satisfactorily to physical test results[1,2]
2. Indicates stress for short columns never exceeding the yield strength of the material
3. Permits analysis of any length column because of smooth transition with the Euler curve for slender columns
4. Readily applicable to any material for which mechanical data are known

This data sheet outlines a procedure for the

[1]References are tabulated at end of data sheet.

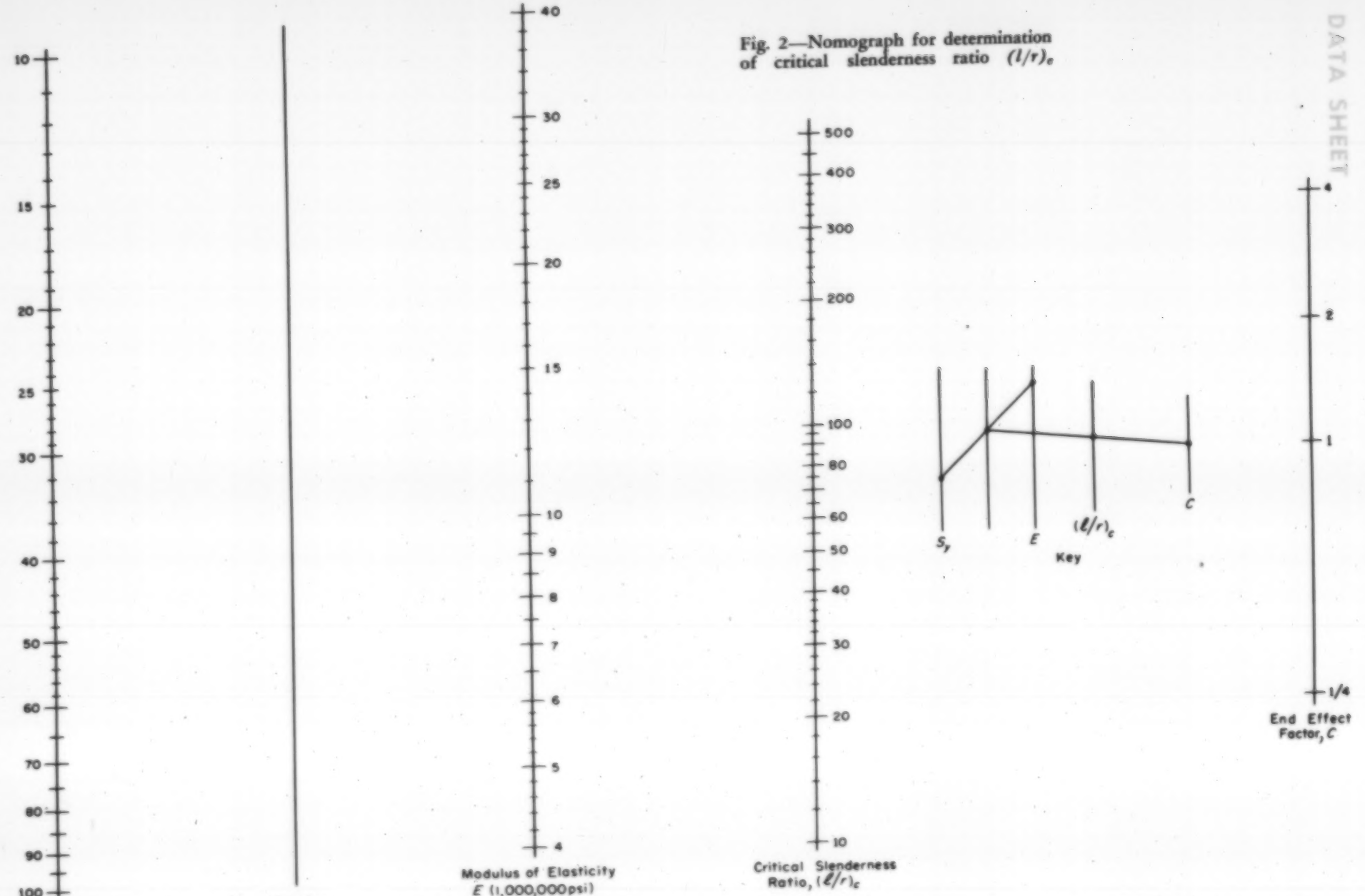
Fig. 1—Typical parabolic type column curve showing smooth transition with Euler slender column curve



Nomenclature

A	= Area of cross-section, sq in.
C	= End condition factor
d	= Round rod diameter, in.
E	= Modulus of elasticity, psi
f	= Factor of safety
l	= Unsupported column length, in.
l/r	= Slenderness ratio
$(l/r)_c$	= Critical slenderness ratio
r	= Least radius of gyration of cross section, in.
P_c	= Maximum axial force, lb
P_w	= Working axial force, lb
P_c/A	= Maximum column stress, psi
P_w/A	= Working column stress, psi
S_y	= Compressive yield strength, psi

Fig. 2—Nomograph for determination of critical slenderness ratio $(l/r)_c$



rapid stress analysis of axially loaded columns of any degree of slenderness by the combined use of the parabolic and Euler column formulas. In *Fig.* 1 is shown a combined parabolic and Euler curve. The salient features are that the curve originates on the *Y*-axis at the yield strength of the material, S_y, and becomes tangent to the Euler curve at a critical slenderness ratio, $(l/r)_c$, which corresponds to a stress of $S_y/2$. The effect is to reduce the yield strength found for short compression blocks with increasing column slenderness. For columns having slenderness ratios greater than $(l/r)_c$, *Fig.* 1, the Euler column formula is used.

The general parabolic formula for maximum column stress is

$$\frac{P_c}{A} = S_y - \frac{S_y^2 \left(\frac{l}{r}\right)^2}{4 C \pi^2 E} \qquad (1)$$

and the Euler column formula is

$$\frac{P_c}{A} = \frac{C \pi^2 E}{\left(\frac{l}{r}\right)^2} \qquad (2)$$

Since $P_c/A = S_y/2$ at intersection of the curves, the critical slenderness ratio $(l/r)_c$ can be found in terms of S_y by substituting its value in either

Table 1—Factors for Various End Conditions

End Conditions	Factor *C*
One end fixed, other end free	¼
Round, pinned or hinged ends	1
One end fixed, other end guided	2
Fixed ends	4
Both ends square, flat surfaces	4

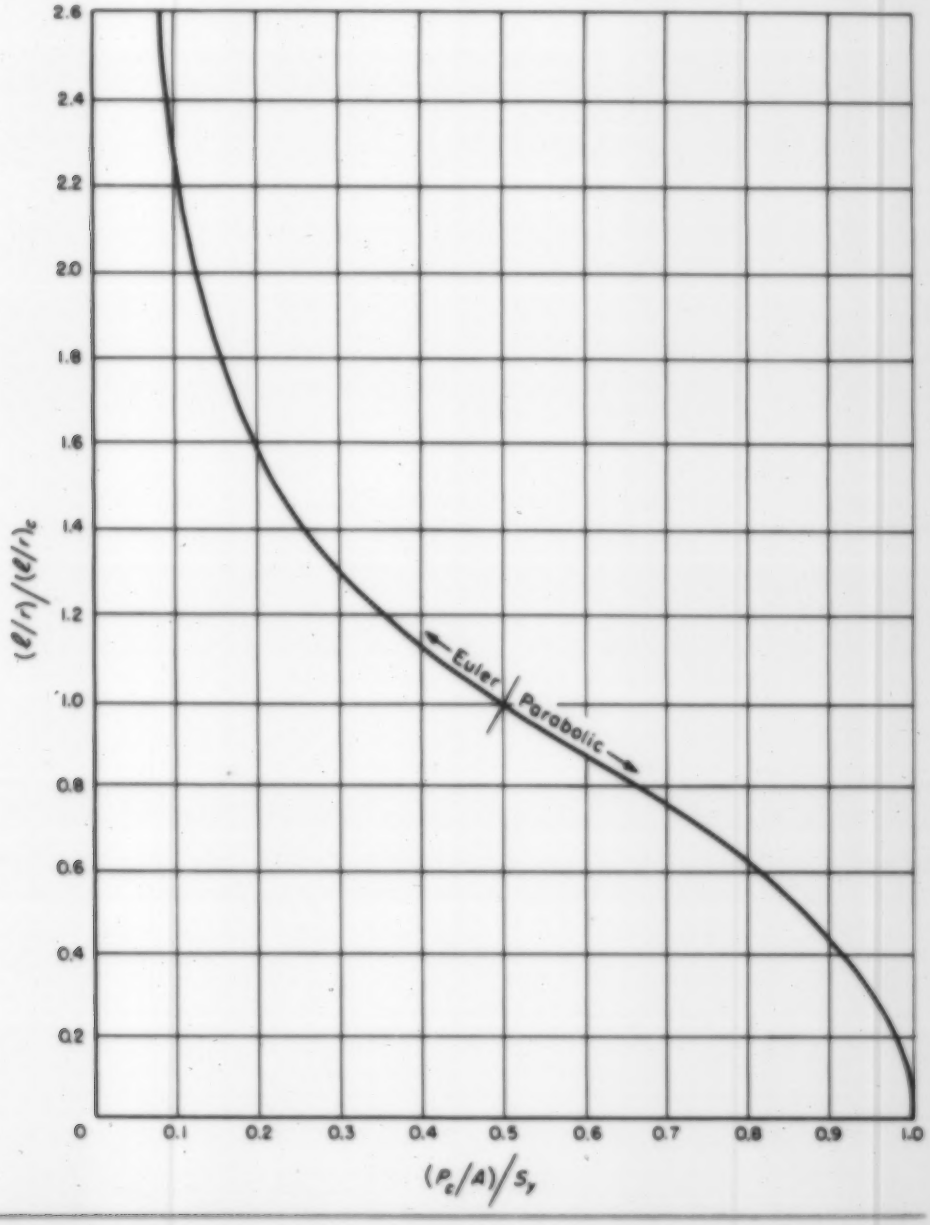


Fig. 3—Curve of $(l/r)/(l/r)_c$ *versus* $(P_c/A)/(S_y)$ for determining the portion of yield strength that can be utilized for various column slenderness values

Equation 1 or 2. Thus,

$$\left(\frac{l}{r}\right)_c = \pi\sqrt{\frac{2CE}{S_y}} \qquad (3)$$

Effect of End Conditions: It is known that different terminating means for columns have more or less ameliorating effects on the stresses which can be endured before failure occurs. Equations 1, 2 and 3 contain a factor C which takes into account this effect. In *Table* 1 are given theoretical values of C for different end conditions. An actual column having end conditions required for a factor $C = 4$ is rare. For example, a value for C of only 2 has been permitted for aircraft column members welded at both ends and presumably fixed.[8] Some designers advise the use of a maximum value for C equal to 1 for general column design.

Safety Factor: In practice, influences such as eccentricities of loading; initial stresses, bends and kinks; inhomogeneity of real materials; and lack of co-action between members of built-up sections[4] make the imposition of a factor of safety mandatory in the case of columns. Timoshenko and MacCullough[5] suggest a safety factor of 2½ to 3 for parabolic column formulas to obtain working stresses. A parabolic formula currently specified by the AISC[6] for structural steel columns with an l/r to 120 is similar to the formula resulting when $E = 29 \times 10^6$ psi and $S_y = 33{,}000$ psi are substituted in Equation 1 and a safety factor of 1.94 is employed. Seely[1] discusses a common parabolic formula which can be obtained from Equation 1 using a safety factor of 2.2. The designer having no other criterion would do well to remain within the range 2.2 to 2.5 for ductile materials under steady load, and 3 to 3.5 for brittle materials.[7] These factors are recommended also for analysis employing the Euler formula.

Chart Solutions: The nomograph of *Fig.* 2 and the chart in *Fig.* 3 offer a ready solution for analyses involving Equations 1, 2 and 3 for the materials commonly employed in design. In ordinary use the critical slenderness ratio $(l/r)_c$ is first found from the nomograph in *Fig.* 2. The value of ratio $(l/r)/(l/r)_c$ is then entered in *Fig.* 3 and the portion of yield strength, S_y, that can be utilized is determined. Working stresses are obtained by application of a suitable safety factor. In regard to the accuracy of the charts, answers to the examples following are all within 1 per cent of true values found by actual calculation employing Equations 1, 2 and 3.

EXAMPLE 1: A pin-connected mild steel pushrod has a 1-inch diameter and an unsupported length of 25 inches. Determine the maximum force that can be transmitted axially.

The minimum radius of gyration $r = d/4 = 0.25$-inch. Thus the slenderness ratio $l/r = 25/0.25 = 100$. Assuming $S_y = 40{,}000$ psi, $E = 30 \times 10^6$ psi and $C = 1$, from *Fig.* 2, $(l/r)_c = 122$ approximately. Thus $(l/r)/(l/r)_c = 100/122 = 0.82$ approximately. From *Fig.* 3 at $(l/r)/(l/r)_c = 0.82$, $(P_c/A)/S_y = 0.66$. Since $P_c/A = 0.66\ (40{,}000) = 26{,}400$ psi maximum, $P_c = 26{,}400\ (\pi/4)\ (1)^2 = 20{,}800$ lb maximum. Therefore, the maximum working axial force $P_w = P_c/f = 20{,}800/2.2 = 9{,}440$ lb.

EXAMPLE 2: What would be the effect of substituting 2024-T4 aluminum ($E = 10.3 - 10^6$ psi, $S_y = 48{,}000$ psi) for the mild steel used in Example 1?

From *Fig.* 2, $(l/r)_c = 65$ approximately and $(l/r)/(l/r)_c = 100/65 = 1.54$ approximately. From *Fig.* 3, $(P_c/A)/S_y = 0.21$. Note that the change in material has shifted the calculations from the parabolic to the Euler column formula range. Since $P_c/A = 0.21\ (48{,}000) = 10{,}080$ maximum psi, $P_c = 10{,}080\ (0.7854) = 7{,}920$ lb maximum. Here the maximum working axial force $P_w = 7{,}920/2.2 = 3{,}600$ lb.

EXAMPLE 3: A forming machine requires a steel knockout pin $\frac{5}{16}$-inch in diameter with one end fixed in a holder. The pin holder is actuated by gradual application of a spring which develops a maximum force of 1000 pounds. Find the maximum projection of a pin capable of withstanding a machine jam when all spring pressure would be applied axially. Assume a factor of safety of 2.2 and $S_y = 40{,}000$ psi.

Since $P_c = P_w f = 1000\ (2.2) = 2200$ lb, $P_c/A = 2200/(\pi/4)\ (5/16)^2 = 28{,}700$ psi maximum. Thus $(P_c/A)/S_y = 28{,}700/40{,}000 = 0.72$. From *Fig.* 3 at the point $(P_c/A)/S_y = 0.72$, $(l/r)/(l/r)_c = 0.75$ approximately. From the nomograph in *Fig.* 2, using $S_y = 40{,}000$ psi, $E = 30 \times 10^6$ psi and $C = 1/4$, the critical slenderness ratio $(l/r)_c = 61$. Then $l/r = 61\ (0.75) = 45.8$, and finally the maximum allowable projection $l = r\ (l/r) = 45.8\ (1/4)\ (5/16) = 3.57$ inches.

Conclusion: It is not the intent of this data sheet to advise a departure from satisfactory use of the many existing empirical column formulas specified in various codes and found in the publications of materials manufacturers. However, where design freedom exists, the parabolic column formula will indicate stresses that are in good agreement with tests and are readily determined for any material. When used in conjunction with the Euler formula, it enables the rapid comparison of alternate designs of any degree of slenderness as well.

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Basic Factors in Selecting

Induction Motors

DESIGN ABSTRACTS

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THE ac squirrel-cage induction motor has many characteristics which make it a desirable type of motive power to drive industrial machines. It is the simplest, least expensive type of motor that can be built, one of the most efficient and requires the least amount of maintenance and care. A wide range in performance characteristics can be obtained with these motors, by the proper design of the motor and its control.

The National Electric Manufacturers Association has set up a series of performance standards for several designs of squirrel-cage motors. A knowledge of these standards and what they mean in terms of machinery performance is essential in making proper drive selections.

The NEMA-B motor is the standard garden variety. Its speed-torque characteristics are basically as shown in *Fig.* 1. At standstill and with rated voltage applied to the motor it will develop about 175 per cent of its full-load torque. Full-load torque of any motor is the amount of turning effort the shaft exerts when it is operating at its full rated horsepower load. The NEMA-B motor will therefore exert a sudden

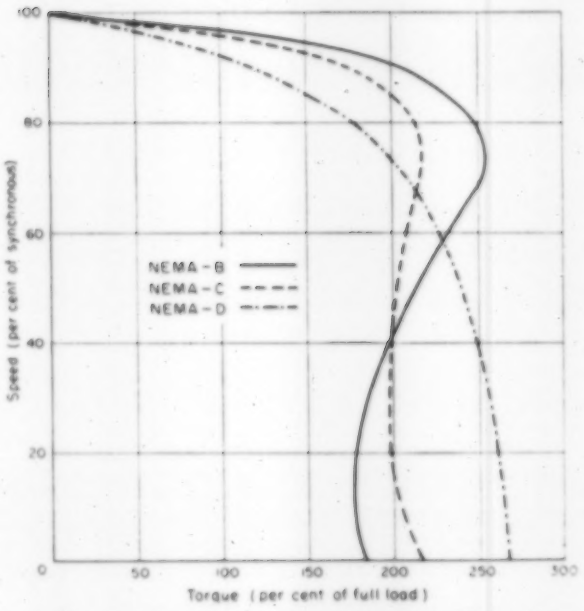

Fig. 1—Speed-torque curves of NEMA induction motors

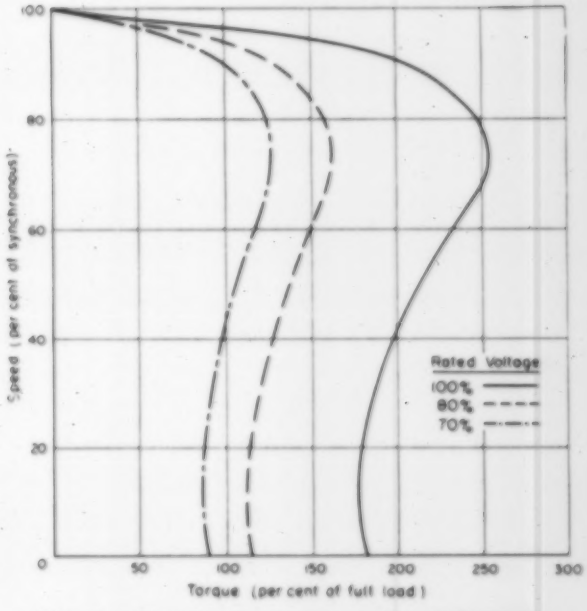

Fig. 2—Speed-torque curves for NEMA-B motor with percentages of rated voltage

torque on the shaft equal to about 175 per cent of full-load torque, and as the motor picks up speed the torque will reduce slightly until about 25 per cent speed is reached. From this point to about 75 per cent speed the torque increases and then, as the speed increases further, the torque decreases very rapidly until at synchronous speed there is zero torque. This, of course, means that an induction motor must always operate at some speed lower than synchronous speed.

The NEMA-B motor has excellent operating characteristics; its speed-torque curve shows that there is very little speed change over a wide change in load. Its efficiency is high, and its cost is usually the lowest. It does, however, have a rather high current during starting, and care should be used in applications requiring frequent starts or starting loads with extremely high inertia.

Another type of NEMA standard is the NEMA-C motor, also shown in *Fig.* 1. This motor has a torque of about 200 per cent of full-load torque at standstill and a maximum torque of about the same value. This type of motor should be used on applications where there is a high-friction starting load but not much inertia.

The NEMA-D motor also shown in *Fig.* 1 is a motor which has a starting torque of better than 250 per cent of full-load torque. Torque then gradually decreases as the speed increases. This type of motor has excellent starting characteristics, and the amount of heating in the motor is much less, during the starting period, than the NEMA-B or C motors. This type of motor should be used where the starting is frequent or where there is a very high inertia to be started. For steady running, efficiency of this motor is a little lower than the B or C motors, and speed is not quite as constant as the load varies.

By the use of suitable control, shapes of the speed-torque curves of any induction motor can be varied. *Fig.* 2 gives an indication of what can be accomplished by voltage control. The voltage may be reduced by transformers, reactors or resistors. Torque obtainable on any part of the speed-torque curve always varies as the square of the voltage. If voltage is 80 per cent of motor rated voltage, torque will be 64 per cent of the full torque value at any point on the curve.

Braking: Decelerating torque, or braking torque, can be developed with induction motors. This can be done by plugging or reversing the power to the motor or by applying a direct-current voltage to any two terminals of an induction motor.

Braking torques developed by the various standard NEMA motors when reverse power is applied while the motors are decelerated from full speed to zero speed are indicated in *Fig.* 3. This type of deceleration control must provide means to disconnect the motor at precisely the zero speed point, or the motor will reverse. In many machines the slightest reversal of shaft rotation is detrimental.

The family of curves in *Fig.* 4 shows the braking torque developed by an induction motor when a dc current is applied between any two motor terminals. The family of curves is for the same

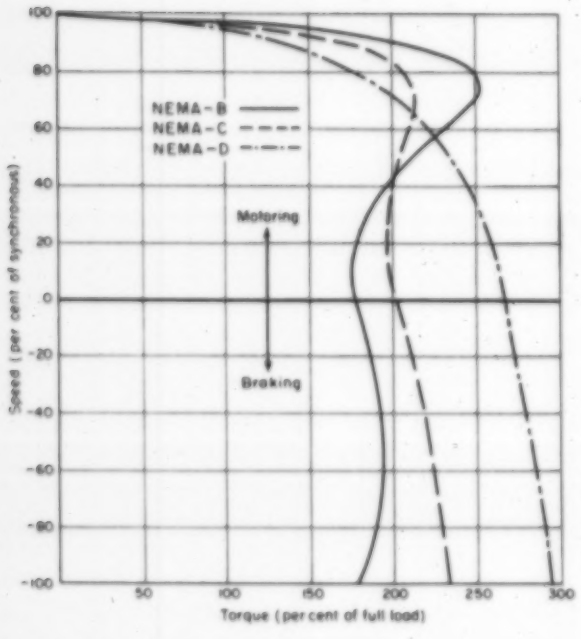

Fig. 3 — Motoring and plugging (braking) speed-torque curves for some NEMA motors

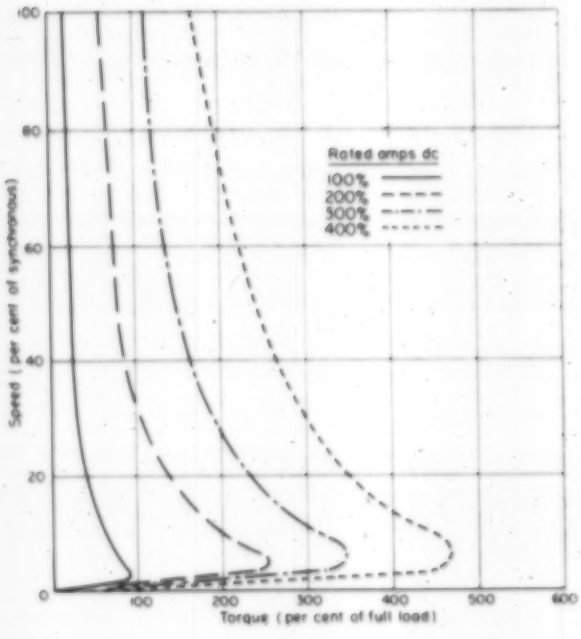

Fig. 4—Braking torque-speed curves for NEMA-B motor with dc voltage applied to any two leads

motor but with different values of dc current. Amount of braking can be varied over a wide range. This type of braking provides a very smooth stop since torque reduces very rapidly as speed approaches zero. With this type of braking it is impossible for the motor to reverse. For example, it has been used widely in the textile industry for such applications as spoolers, winders, warp-knitting machines, and carpet looms.

Control Selection Factors: When selecting a motor and control for a specific machine, conditions of operation to be met must be fully determined. If a constant speed is indicated during operation, the first consideration should be the induction motor. If speed changes are obtained by pulley changes, or variable-sheave V-belt units, the drive can still be considered a constant-speed drive as far as the motor is concerned. The next consideration, then, is to determine the starting requirements and how these can be met.

When an induction motor is started with full line voltage there is a sudden hammer-blow application of torque. This can be especially severe if there is any backlash in the drive or gears. If there is no damage done to the machine or the material in process, there is nothing to worry about. If, however, the machine requires a smooth application of torque, something other than full-voltage starting must be used. There are many ways by which reduced torque can be applied to the driven shaft:

1. REDUCED VOLTAGE: Any desired starting torque can be obtained with an induction motor by controlling the voltage applied during the starting period, *Fig.* 2. Many forms of controls are available. The simplest and least expensive is the resistor or reactor type where reduced voltage is applied while the operator keeps the start button depressed, and full voltage is applied as soon as the start button is released. This type of control is applicable to all the NEMA type classifications of induction motors. Its advantages are that the starting torque can be readily adjusted, but full torque is always available to start the machine under unusual conditions. After starting is completed, full power of the motor is available to run the machine.

2. SPECIAL TORQUE MOTORS: It is always possible to build special torque motors. Speed-torque curves for the two-value soft-start roving-frame motor used in textile applications are shown in *Fig.* 5, while *Fig.* 6 shows the same for a so-called three-value soft-start roving-frame motor. With either of these schemes the electrician must make the connections that give the proper starting torque. This scheme would be wonderful if there was any assurance that the torque that will just start the machine under most conditions will always start the machine. Unfortunately, there might be cold ambient temperature conditions or a condition of low voltage, when the machine will not start. The result is that the motor is finally connected for maximum torque and the machine starts more rapidly than desirable for best results. With either of these schemes the full power of the motor is not available during the running period except when connected for the maximum torque.

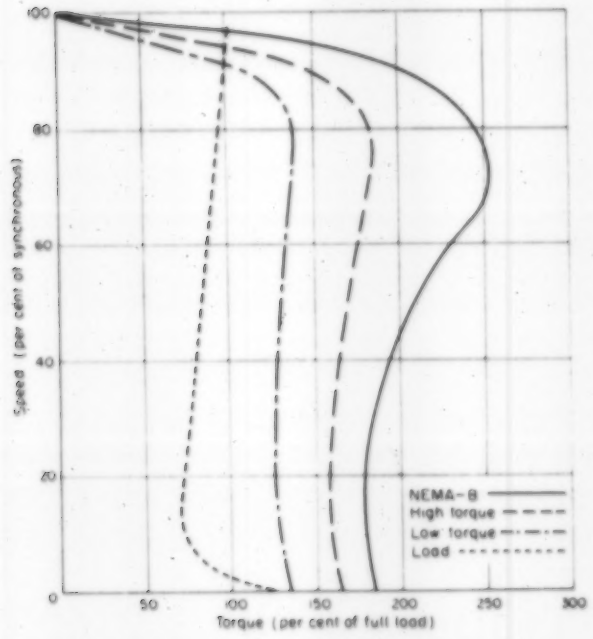

Fig. 5—Speed-torque curves for a two-value soft-start motor and an NEMA-B motor. Low torque connection is series delta. High torque connection is parallel wye

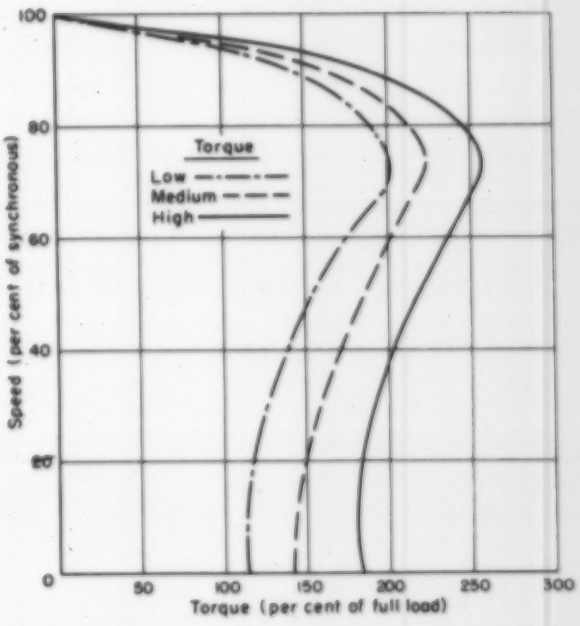

Fig. 6—Speed-torque curves for a three-value soft-start roving frame motor

3. CLUTCHING TECHNIQUES: A centrifugal type clutch allows the motor to start without moving the machine. The tendency for a hammer-blow start is definitely reduced, although there is still some depending on the torque developed by the centrifugal clutch. When the friction weights are too light there is danger of slippage at normal loads. When the weights are too heavy the clutch will not allow the motor to accelerate, and the condition of having the motor solidly connected to the load is approached. For machines that require a very heavy starting torque, friction must be set high in order to be sure that the load is started and maintained in operation at the proper speed.

With the centrifugal clutch there is wear during the starting period. Amount of wear and heat generated in the clutch is a direct function of the mass that has to be accelerated. This type of clutch must always be properly maintained so that there is no slippage at normal operation, since slippage causes eventual destruction.

4. FLUID DRIVES: With the advent of the use of fluid clutches there has been a great interest in using this type of drive to get smooth, slow acceleration. In order for the fluid drive to develop any torque there must be a difference in speed in the drive member and the driven member.

When used with a squirrel-cage motor, this type of drive will usually mean that the motor will accelerate very quickly to the point where torque output of the clutch is greater than the torque developed by the motor. From this point on the machine will accelerate at the same rate as though the motor were solidly connected to the machine. The drive does give a cushion effect to take up any backlash but from this point on there is very little control of the rate of acceleration.

In order to select the most economical drive for any machine, the available characteristics must be known, and how they can be made to meet the requirements of the machine to be driven.

From a paper entitled "Induction Motor Characteristics and Capabilities to Meet Textile Machine Requirements" presented at the AIEE Middle Eastern District Meeting in Reading, Pa., October, 1954.

Factors in evaluating

Electronic Analog Computers

By Chalmer E. Jones

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Berkeley Div.
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IN evaluating analog computers, it must be stated at the outset that equipment and techniques in this industry change rather rapidly. Although informative, past reports on equipment performances may not be correct for present models.

The following is a list of 9 significant points whose observation should give a rather complete summary of a computer's advantages and disadvantages.

1. Construction
2. Reliability
3. Flexibility
4. Expandability
5. Compatibility
6. Resettability
7. Accuracy
8. Cost
9. Convenience

Construction: Construction refers to the mechanical structure as well as the electronic physical system. It may be broken into three categories:

MECHANICAL STRUCTURE: See that the unit is mechanically strong; that there are enough supports for the heavy equipment; and that it is not easily susceptible to undue scratches and mars. Portability may be an important factor.

CHASSIS LAYOUT: Investigate the chassis layout and general construction. See if the individual units such as amplifiers, function generators and multipliers are easily accessible. It is often desirable to be able to change a tube or set potentiometers from the front. The easier it is to service and follow the electronic circuits, the less time will be spent in troubleshooting and maintenance.

COOLING: Investigate to see that the cooling system is adequate and that there is enough air moved around all of the components which give off heat. As most resistors are sensitive to thermal changes and much error is caused by thermal drift, these units should not be subject to great temperature rises when the unit is turned on. The temperature should not fluctuate while the computer is in operation and the temperature rise in the system should not be more than 70 F above ambient. In some cases, the components may melt if the ambient temperature is above 85. Some installations require air conditioning which may effectively add hundreds of dollars to the price.

Reliability and Maintenance: Reliability for this purpose will be defined as the ability of the equipment to keep operating.

Examine the schematics to ascertain the simplicity of the circuits and what generally might go wrong. Look at the chassis themselves to see how complicated the unit seems and what might be expected in the way of troubleshooting and preventive maintenance.

See if the schematics list the voltages and waveforms at various

points and in addition to this, if they list resistances to ground at strategic points. If the amplifiers are chopper stabilized, what type of choppers and tube components are used? What type of relays are they using? Are they going to last for some time or will they require early replacement?

Are the components of good quality, especially the passive RC (resistance - capacitor) components? For quality work, it is recommended strongly that all computing capacitors be polystyrene. How often will it be necessary to set potentiometers, not only the zeroing potentiometers but others such as coarse adjustment, gain and various balancing potentiometers in the circuits?

Flexibility: Flexibility refers to the computer's ability to solve a wide variety of problems. For instance, determine the range of time constants available in the combination of RC components and whether it is possible to operate as a repetitive computer. That is, may the solutions be presented several times a second and viewed on a scope? Three other points are also important and should be checked.

1. ***The possibility of using the computer with actual equipment.*** May an actual system component be connected by means of transducers to the computer and the computer represent or analog the balance of the system?

2. ***Flexibility of Amplifiers.*** Are the amplifiers of predetermined function or may any amplifier be used to integrate, sum, sign change, etc.? See if the passive resistors and capacitors are fixed to the amplifiers. If they are fixed, there may be times when amplifiers connected as adders are available but the problem requires one more integrator.

3. ***Diversity of Number of Components.*** Are there enough resistors and capacitors for a wide range of problems? Are there such computing components as decade resistances, decade capacitors? Are there operational relays which may be connected directly to the output of the amplifier? Does the computer allow for a holding of the problem; i.e., may the problem begin to go to solution and then be stopped at any point in time?

Expandability: In the majority of computer facilities, it is found that after a period of time, more equipment is needed. It is therefore advisable to investigate just how much the computer may be expanded. Is it possible to begin with a small number of components and later add to these to build a computer facility of any size? Can the new models be incorporated into existing equipment and can the new computing components and conveniences be added to the unit? What would be the maximum facility which is possible with any one type? In addition, consideration should be given to the convenience or accuracy lost in expanding.

Compatibility: This is a measure of how easily the computer is adapted to other equipment such as read-in and read-out equipment or analog equipment by other manufacturers. Has sufficient space been allowed on the computer setup panel or patch board so that other equipment may be added whether it be the same manufacturer or other manufacturers? Do the dc amplifiers supply enough power to drive the pen recorders directly or must external amplifiers be used? Are the units in the computer compatible with themselves; that is, are the capacitors furnished of such a magnitude as to operate with the proper time constants with the rest of the computer? If the computer incorporates servo mechanisms, then the amplifiers in all probability should be stabilized.

Resettability and Repeatability: It is often necessary to break down or take off one problem and continue at some time in the future. Therefore, the ease with which one can reset the computer back to its original operating condition becomes important. This feature should perhaps be broken down into the analysis of each of the components and the ease and accuracy with which each may be returned to its original position. For instance, if the potentiometers are set by their own dial, then it should be fairly easy to return them to a previous setting. However, if they must be zeroed or nulled to another potentiometer, this operation becomes more time-consuming. If the passive resistance and capacitor components are predetermined and marked, it becomes fairly easy to reset them into the problem. If they are unstable however, and have drifted, then new measurements must be taken to reset the problem.

There may be a certain amount of resetting necessary between computer runs. If the amplifiers are unstable and it is a complicated problem, many of the integrator amplifiers, as well as the multipliers, will have to be rezeroed.

Repeatability is a measure of the accuracy of succeeding solutions and depends upon the stability and interchangeability of the individual components. It is necessary to examine the accuracy at which a problem will repeat itself. How close will one solution be to a solution using the same or different components at some other time? Will one succeeding run vary greatly from the next?

Accuracy, Cost and Convenience: These three factors are interrelated. Such things as automatic digital potentiometer settings and digital readout add convenience but are extremely costly. For the same accuracy, one may sacrifice convenience to keep cost down. For instance, if resistors should be 5 per cent resistors (within 5 per cent of stated value), the operator may measure the actual values of these resistors. By using the actual values in the computer setup, greater accuracy may be had.

The accuracy required in the computer depends upon the problem to be solved. This often may be investigated by analyzing the variables and coefficients in the problem. If it is possible to measure the coefficients in a particular problem to an accuracy of 10 per cent and the computer introduces 3 per cent error, the root-mean-square error (square root of 3^2 plus 10^2) would be 10.45 per cent. It then becomes apparent that it is more desirable to improve the accuracy of measurement from 10

per cent to 9 per cent than to go from a computer of 3 per cent accuracy to a perfect one. In the evaluation of computer accuracy, it may be generally assumed that the computer introduces errors in three major ways: (1) Inaccuracies in the passive resistance-capacitor computing components, (2) drift in various active components (amplifiers, multipliers) and (3) phase shift.

Errors which are caused by the RC components are principally due to drift of accuracies and value.

If nominal 5 per cent components are used, then errors may be noted by assuming the resistors and capacitors to be the value stated. On the other hand, a more subtle error may be noticed if the resistors and capacitors change with time. It is therefore wise to make sure that the resistors are not subjected to rapid temperature changes and are of good quality with respect to drift.

Drift is arbitrarily broken into two types, random and long term. Random drift is defined as that drift which will introduce errors while making a computer run. Long-term drift is that drift which will amount in negligible error during any one problem run, but after a run is completed will necessitate rezeroing and resetting. In some linear servomechanism problems, where only the transient is of importance, the drift may be considered as part of the initial conditions and when subtracted will make very little difference. In this case, the random drift might be more important.

In measuring drift, the measurement should be referred to the grid as this reduces it to a number which is not dependent upon the ratio of the impedances. Random drift would be defined on the basis of a short-term period, such as 3 minutes; that is, the maximum grid voltage would never exceed so many millivolts or microvolts in the stated period. Long term drift would be stated over two or three days. If the amplifier is chopper stabilized, then a figure might be given for long-term drift which the amplifier would never exceed.

There may be dynamic error. If the computer introduces frequency sensitive errors of its own such as phase shift, the analog or simulated system no longer represents the desired system. Therefore, it is necessary to investigate the frequencies at which these phase shifts occur.

A concept of a figure of merit combining both the phase shift and the drift can now be introduced. It can be seen that the time of computation is limited by the accuracy required. For instance, if you want to stay within 1/10 per cent accuracy in an amplifier, allowable computing time would be dependent on the time for the drift to reach 1/10 of a volt on the output. Therefore, in one amplifier it may mean a computing time of one minute while in another it might be 10 or 20 minutes. However, the frequencies which may be handled by any one amplifier or servo multiplier are limited by the phase shift. The highest frequency which a component will handle can be defined as that frequency at which the phase shift is 0.01-radian or less.

Thus, one amplifier might reach one or two cycles per second before this phase shift is introduced while another may go up as high as two or three hundred cycles per second. The highest frequency component that any one unit would be able to handle during computation is a function of the combination of the computing time and the frequency which could be passed without reaching 0.01-radian phase shift. The figure of merit denoted by R would then be $R = ft$, where f = frequency at which phase shift is less than 0.01-radian and t = time for drift to reach 0.1 per cent. Thus one amplifier might have a figure of $R = 1000$ indicating that it can handle a frequency component of 1000 cycles whereas another might be 4000; R is the number of cycles of highest frequency contained in the longest time. Two computers may be compared by means of their R values. Comparing drift rates, computing times, or maximum frequency alone is not significant enough.

From a paper entitled "Evaluation Techniques for Electronic Analog Computers" presented at the Analog Computer Summer Seminar at Pennsylvania State College, June, 1954.

All-Metal Sandwich Structures

. . . for high-temperature applications

By John V. Long and George D. Cremer

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San Diego, Calif.

BASICALLY, a honeycomb structure, such as pictured in *Fig.* 1, may be classed as an anisotropic, integrated sheet-metal assembly. Foil-thin ribbons arranged in honeycomb pattern comprise the core, which is securely sandwiched between thin metal facing or skins. These facings are the prime load-bearing members, and through complete surface stabilization high compression strengths can be realized, even in the thinnest gage faces. The core performs the vital function of providing essentially continuous support to the facings to prevent buckling under compression while at the same time transmitting shear stresses. The resulting structure permits high strength-weight ratios to be achieved.

Adhesive-bonded sandwich is used principally as a secondary strength structure, where sustained operational temperatures are below

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about 350 F. All-metal honeycomb sandwich construction, on the other hand, offers a practical solution for elevated temperature applications up to at least 1500 F.

High-temperature all-metal sandwich structures can successfully be fabricated by using special brazing techniques. The resulting structures exhibit the following desirable properties at elevated temperatures:

1. High strength-weight ratio
2. High stiffness factor
3. Good thermal resistance
4. High vibration damping ability
5. High fatigue resistance
6. Acoustical insulation

Furthermore, the all-metal sandwich structure permits composite constructions with special properties, such as blast panels and permeable components.

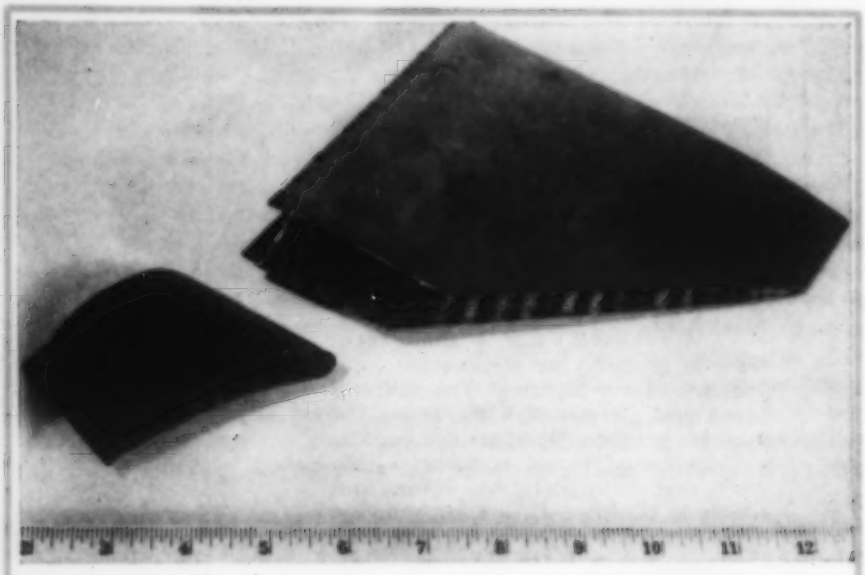


Fig. 1—Typical high-temperature all-metal sandwich structures

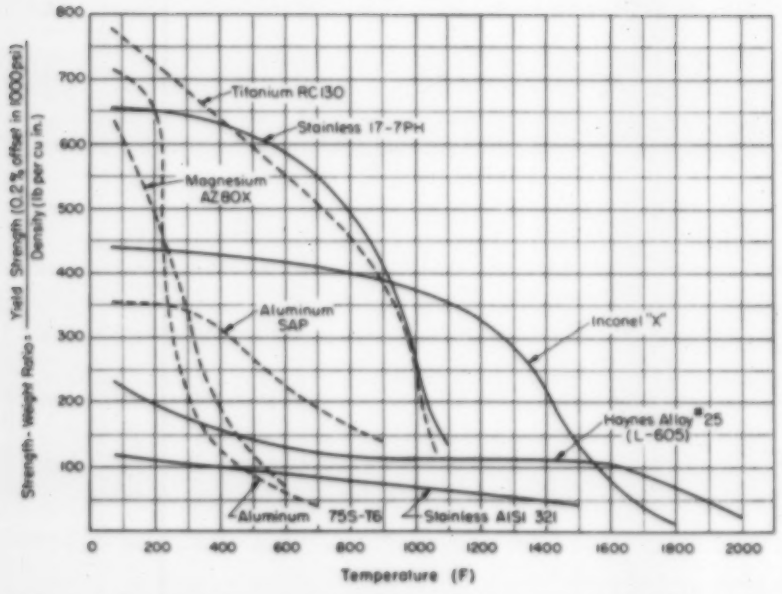


Fig. 2—Comparative strength-weight curves for several alloys used in sandwich structures, showing effect of temperature

Sandwich Materials: Facing or skin thicknesses for structural sandwich sections usually lie within the range of 0.010 to 0.030-inch, while core stock runs from 0.001 to 0.010-inch. Suitable high-temperature, corrosion-resistant metals include AISI 321, Armco 17-7PH, Inconel X, Multimet, and Haynes Alloy 25 (L-605).

Comparative curves for a number of alloys, showing yield strength per unit weight versus temperature, are presented in *Fig.* 2. Below about 900 F, the superiority of 17-7 precipitation hardening stainless steel is evident, while higher temperatures indicate the use of Inconel X. Extreme temperatures require L-605.

Structural Properties: Remarkable stiffness is added to thin faces by stabilizing them with honeycomb core. By means of high-temperature brazing, strength of all-metal honeycomb sandwich structures can be maintained at elevated temperatures.

Compressive strength of the sandwich is greatly dependent upon cell design and through proper choice of cell configuration and material values as high as 4,000 psi have been realized in 2 mil, ¼-inch cell core.

Creep properties of high-temperature brazed construction are generally favorable at all temperatures within the application range. Strength values are dependent upon a given sandwich design. As a specific example, physical property testing of a heat treated panel ½-inch thick, constructed of 17-7PH steel with a 0.002-inch, ¼-inch square-cell core and 0.015-inch faces yielded the values listed in *Table* 1.

Table 1—Physical Properties of Typical Sandwich Structure*

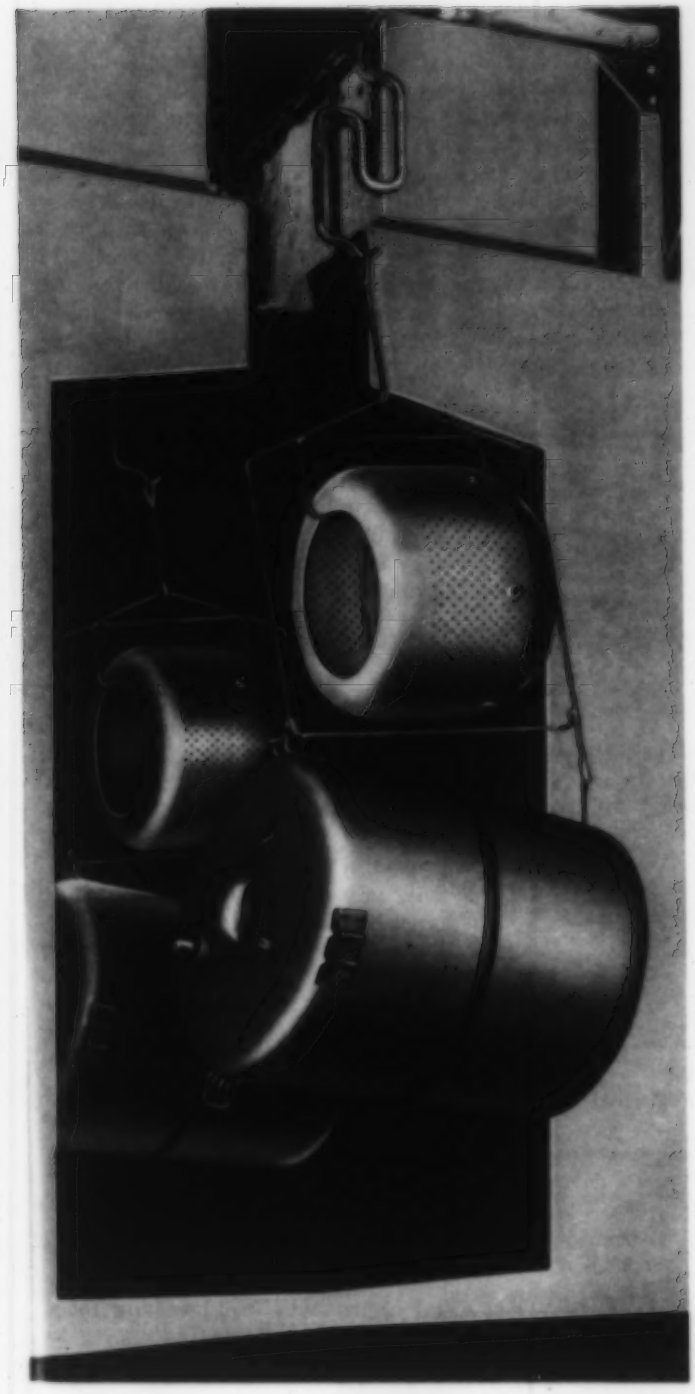
Property	Strength (psi) 75 F	800 F	1000 F
Face tension (after brazing)	175,000	115,000	80,000
Edge compression	180,000	130,000	80,000
Flat compression	4,000	2,600	1,300
Core shear, maximum	500	400	350

*Heat treated ½-in. panel, constructed of 17-7PH steel with 0.002-in., ¼-in. square-cell core and 0.015-in. faces.

HOT H_2SO_4 Corrosion Stopped COLD

by *Carpenter*

Stainless No. 20Cb



Appliance Manufacturer Eliminates Pickling Tank Maintenance Costs

70,000 lbs. of steel parts for automatic washing machines are cleaned daily by a 10% hot sulphuric acid solution at stage five in a nine-stage continuous pickling machine. Taming the H_2SO_4 solution is a 20′x9′x4½′ spray booth lined with Carpenter Stainless No. 20Cb plate.

Rubber lining previously used resulted in frequent and costly breakdowns. Carpenter Stainless No. 20Cb requires no maintenance and shows no sign of corrosive attack after lengthy use. Heating coils submerged in the H_2SO_4 solution, as well as nozzles for the spray system, are also made of this super corrosion-resistant alloy.

Carpenter Stainless No. 20Cb gives cost-cutting freedom from corrosive attack by a long list of other acids, liquids and gases.

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Stainless Tubing & Pipe

DESIGN ABSTRACTS

Core Design and Construction: Steel and high-alloy sandwich cores are usually manufactured in square, hexagonal honeycomb, or wave-form cell types, *Fig.* 3, although numerous other special core designs have been experimentally produced.

The "Squarecell" type core, shown at the top in *Fig.* 3, may be collapsed if grinding or machining operations are required. Such straight-cell cores are said to be "anticlastic," which means that when the core is bent in simple curvature it reacts by assuming a saddle shape, *Fig.* 4. The expected convex face becomes concave in a direction perpendicular to the bend line.

Another interesting core, notable for its optimum strength-weight design, is commonly known as "egg crate." In this core the longitudinal and transverse ribbons are each slotted half way and then simply assembled slot to slot. This simple egg-crate core resists bending along the longitudinal and transverse axis, intermediate bending between these directions is acutely anticlastic.

The types of core just described are in general not suited for sandwich parts having severe two or three dimensional curvature. Square-cell cores having narrow node bonds as compared to the node width, *Fig.* 3, can accommodate slight bending, providing the radius is ample or the core height relatively shallow. Straight-cell cores, on the other hand, may be damaged if bending is attempted in other than the normal mode.

A number of all-purpose honeycomb cores have been developed primarily to accommodate curved sandwich applications. Two flexible core designs which have been employed in high-temperature all-metal sandwich are shown in *Fig.* 5. One is a finely corrugated core, assembled in square-cell fashion, which exhibits great flexibility, while the other is stabilized by longitudinal ribbons.

While adhesive bonding and resistance welding are the two chief methods of assembling ribbons into core, other techniques include wire stitching, eyeletting, and slotting. Another process not employing ribbons but rather starting from a single sheet makes core in a manner similar to manufacture of "expanded metal."

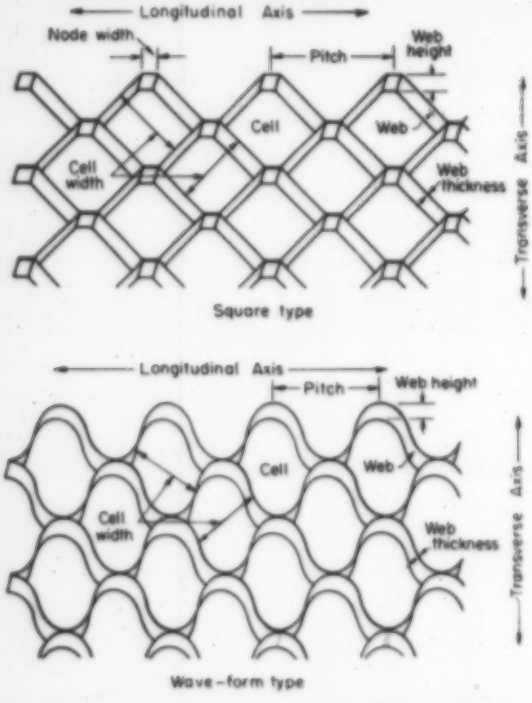


Fig. 3—Sandwich cores of square and wave-form cell types

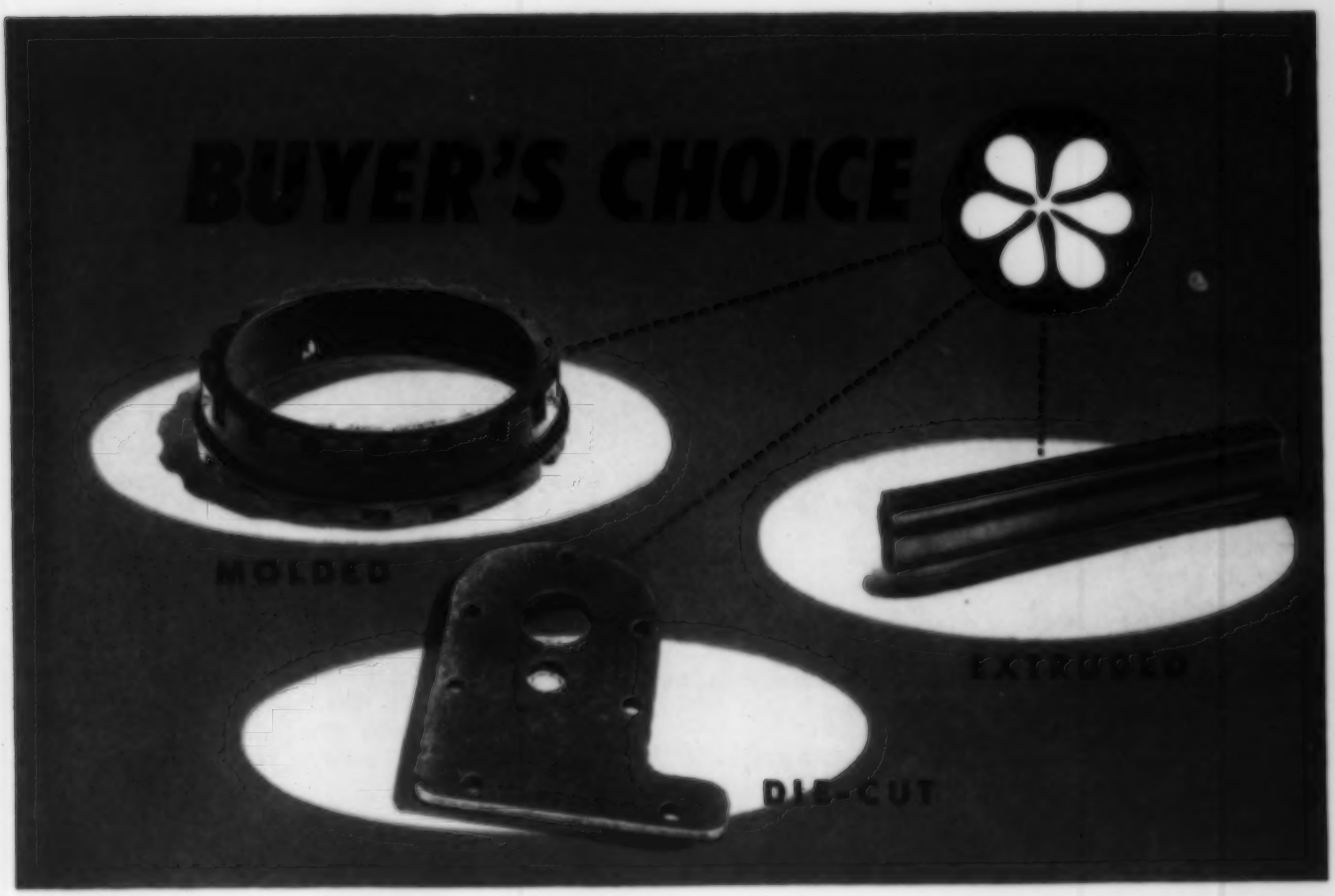
Fig. 4 — Anticlastic sandwich core which assumes a saddle shape when bent in simple curvature

Core Contouring: Machining or grinding flat honeycomb core is not a serious problem if the core can be collapsed for the operation. However, if the core cannot be collapsed or the surface is to be contoured, a real problem presents itself, since tolerances for brazing must be within plus or minus 0.002-inch. Several solutions have been found in practice. One method freezes the expanded core in ice and performs the necessary milling operations at subfreezing temperatures. Another employs a plaster of Paris composition to hold the core for contouring.

Bonding: A high-strength bond between face skins and honeycomb core can be obtained in all-metal sandwich structures. Two principal approaches, welding and brazing, have been investigated.

Resistance welding has definite possibilities. Under the best conditions obtainable, however, only about 25 per cent of the core-end area could be considered as satisfactorily welded to the faces.

Brazing assures a continuous, high-strength metallurgical joining of components. Due to the formation of fillets between mating surfaces, greater bond area results



*ACADIA SYNTHETIC RUBBER PARTS ARE MADE ALL 3 WAYS!

With Acadia you have a *choice!* Not only molded rubber . . . not only molded and die-cut . . . not only extruded rubber . . . but rubber parts any way you require! Better yet, Acadia uses whatever method the requirements of the job and you dictate is the *best* way to do it.

Acadia is especially sensitive to your specifications. We will process synthetic components for oil-resistance—good aging properties—resistance to heat—any characteristic you're seeking, or a combination of characteristics. Acadia parts are cut, molded or extruded to all required shapes, sizes and types, with almost unlimited applications.

Also, we offer Acadia SILICONE Rubber, molded or extruded for gaskets, seals, "O" rings, washers, sheets, cut-parts and packings. This is the rubber that will stay resilient at 100° *below* zero, or 500° above!

There's an Acadia Sales Engineer near you to serve you. Write us today, and we'll put him in touch with you immediately.

ACADIA Synthetic PRODUCTS

DIVISION OF WESTERN FELT WORKS

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MANUFACTURERS AND CUTTERS OF WOOL FELT

with attendant uniform stress distribution. Also, the skins spanning each cell are further stiffened or stabilized—a significant advantage when relatively thin faces are employed. Furthermore, the brazing alloy infiltrates the node laps with consequent sharp improvement in their column and shear properties. With excess braze material, sandwich strengths increase; however, weight economy suffers.

Brazing Fabrication: Sandwich fabrication involves a number of considerations, of which the primary ones are:

1. Proper prepositioning of brazing materials.
2. Correct positioning of structure components and fixtures.
3. Accurate maintenance of metal-to-metal contact between faces and core of the assembly during the brazing-joining operation.
4. Controlled heating and cooling rate to prevent warpage and stressing of the part (Brazing temperatures are about 1900 F).
5. Maintenance of adequate atmospheric protection to insure a clean, nonoxidized assembly and high quality braze metal joints.
6. Controlled post heat treatment operations to develop desired metallurgical conditions within the sandwich materials.
7. Sizing, coining, or other plastic deformation of the brazed panel to develop a precise part and/or to effect strengthening by cold work.

The importance of these different considerations must always be judged in combination since even minor repairs to a brazed panel are frequently prohibitive. All-metal sandwich fabrication requires rigid quality and process control throughout each stage of manufacture.

Inspection: While nondestructive testing standards have not been established for all-metal honeycomb structures, practical solutions to this vital problem are possible.

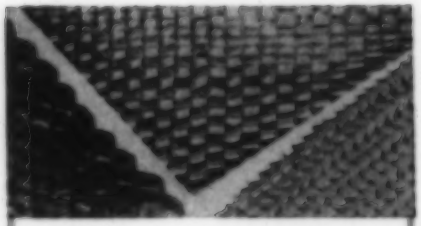


Fig. 5—A square-cell core, top, and two flexible core designs employing finely corrugated ribbon

Since the mere existence of braze fillets in the structure is basic evidence that wetting, capillary flow, and resulting metallurgical bonding has taken place, both X-ray and sonic inspection methods hold real promise for determining fillet existence in all-metal honeycomb structures.

From a paper entitled "High Temperature All-Metal Sandwich Structures" presented at the SAE Aeronautic Meeting in Los Angeles, Calif., October, 1954.

Putting Ideas into Words

THE ability to express ideas in writing and in speaking heads the list of requirements for success. A group of engineers applies a new principle to development of a revolutionary gadget. Results of this effort are summed up in a typewritten report to the head of their department. The report is then mimeographed for the benefit of others in the organization.

The company prepares to put the new product on the market. Writers prepare literature describing its virtues, or explaining how to use it and keep it in working order.

This is indeed useful writing. No piece of company business can begin, progress, and achieve its purpose without effective use of words. Writing, together with reading, is as much an integral part of any business as bones are part of the body.

Research personnel have published countless papers in technical journals, and these have recorded new facts, new basic discoveries, and new theories. Many are recognized the world over as classics, and are cited as authoritative references in their fields. Some opened up wholly new fields for exploration. Others cast new light on known phenomena. Some disclosed new tools for research.

But the recording of ideas and facts is not confined only to engineering and scientific laboratories. Each year, thousands of mechanics, stenographers, accountants, and others write down their suggestions for improving company products and procedures. A gain —for company and employee—is the focusing of attention upon those persons who can think of a better way and who can tell about it with words on paper.

English extends beyond a single classroom; success or failure is largely due to ability to read, to understand, to speak and to write. Whether at drafting board, desk, machine, or calling on customers, we are all involved, more or less, in communication.

English is an easy language to learn. Making English behave may be a little troublesome. One can play safe by writing dull little sentences, and they, of course, are less frustrating to the reader than involved wrong sentences. But since the sentence written or spoken is what the reader or listener uses as a criterion in judging a person, it is good sense to learn how to become its master.

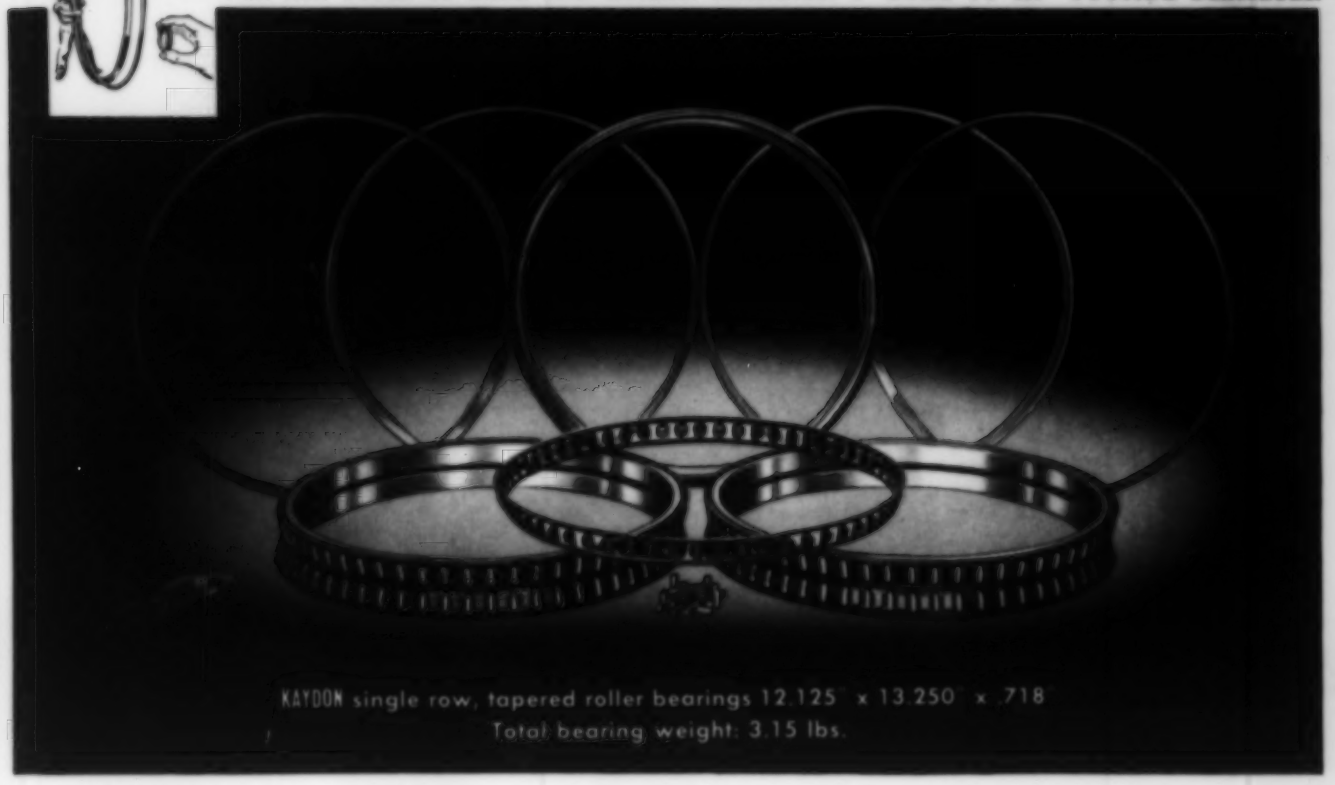
Experience indicates that too many younger employees say to themselves before spreading their wings for a flight with words: "But if I write that report the way I feel it should be written, my boss will think that I am a child." If an engineer, for example, is testing an insulating material and it chars and smells like burned string beans, why not say so?

The technical world needs people whose minds are packed with facts, but with the boldness of imagination to release them in a form that is easy and pleasant to take.

From "Why Study English?" in General Electric Review, *September,* 1954.

Contact KAYDON Muskegon

FOR ALL TYPES OF BALL AND ROLLER BEARINGS: 4" BORE TO 120" OUTSIDE DIAMETER



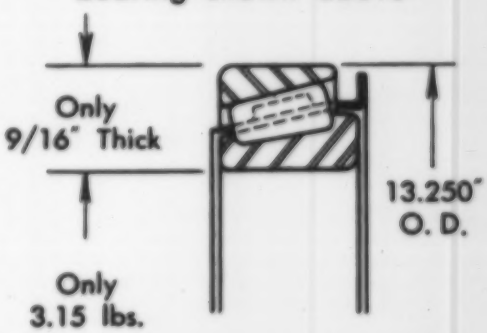
KAYDON single row, tapered roller bearings 12.125" x 13.250" x .718"
Total bearing weight: 3.15 lbs.

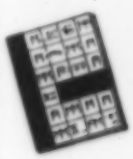
KAYDON creates world's THINNEST tapered roller bearings—REALI-SLIM as a wedding ring

Here's another first by **KAYDON** of Muskegon. We now offer the *thinnest* single row, tapered roller bearings ever made. Even a bride's modern wedding ring, made to proportionate size, would not be as thin or light in weight as one of these *Reali-Slim* bearings.

If you're faced with bearing problems, which involve conserving space and weight, consult **KAYDON** while your product design still is on the drawing board. Remember — for standard bearings or bearings of unusual design you can depend on **KAYDON** for the engineering skill and manufacturing facilities to do your job. It pays to contact **KAYDON** first!

Details of thin section, lightweight bearing shown above





Write for engineering catalog!

For complete data on capacity, seals, separators, standard and *Reali-Slim* "wedding ring" bearings, ask for catalog No. 54.

KAYDON types of Standard and Special Bearings:
Spherical Roller • Taper Roller • Ball Radial • Ball Thrust • Roller Radial • Roller Thrust • Bi-Angular Bearings

THE KAYDON ENGINEERING CORP.

MUSKEGON • MICHIGAN

K-551

PRECISION BALL AND ROLLER BEARINGS

Helpful Literature

(Continued from page 230)

tion motors, both new and current lines, for applications from 1 to 200 hp, is purpose of 12-page illustrated Motor Selector bulletin B-2102. It lists performance characteristics, construction features, dimensions, prices and other information essential in ordering the "right motor for the job."

37. Air, Gas, Oil & Water Valves

Ledeen Mfg. Co.—Line of standard four-way hand, foot, power and solenoid-operated valves is subject of 16-page illustrated bulletin 1010. Dimensions and weights, application diagrams, circuit diagrams, parts list and accessories are included. Valves are designed for air, gas, oil and water applications.

38. Electrical Insulations

Johns-Manville—Use of reinforcing materials gives new series of composite electrical insulations added to Quniterra and Quinorgo line high tensile and tear strength and makes them suitable for motor rewinding and other dynamic applications. Three descriptive folders cover Class H insulation for operating temperatures up to 250° C, Class B for temperatures up to 150° C and economical Class B purified asbestos insulations.

39. Valve Operators

Philadelphia Gear Works—LimiTorque fully automatic valve operators, subject of 21-page illustrated catalog L-54, eliminates manual operation of valves. It limits amount of torque applied to valve operating parts. Operational details are shown.

40. Stainless Steel Pipe

Babcock & Wilcox Co., Tubular Products Div.—Methods of bending and joining seamless and welded stainless steel pipe are outlined and problems of light wall vs. heavy wall pipe are discussed in 6-page bulletin TB 356. Table of dimensions and weights of various pipe size schedules and condensed technical data on mechanical and physical properties are included.

41. Fabric Bearings & Parts

Gatke Corp.—32-page illustrated brochure covers applications and describes unique properties of molded fabric bearings, wear plates and other parts. It shows bearings that are grease or oil lubricated, water lubricated, unlubricated and designed for acid-resistant services. Journal sizes are up to 48-in. diameter. Molded asbestos brake blocks, frictions, cones, etc., are shown.

42. Air Line Lubricators

C. A. Norgren Co.—Twenty models with capacities of ½-pt, 1¾ gal and 4½ gal for ¼, ⅜, ½, ¾ and 1-in. pipe sizes are available in line of Micro-Fog lubricators for air tools, air cylinders and other air operated equipment. These units will supply just the right amount of lubricant into compressed air lines with flows ranging from 5 to 250 cfm. Get bulletin No. 496.

43. Voltage Calibrator

Calidyne Co.—Usable wherever accurate voltage measurement over a wide frequency range must be made, the Calivolter is also suitable for calibrating voltage testers and voltage-sensitive devices. This precision electrical instrument is described in 4-page illustrated bulletin 2354.

44. Diazo Reproduction Materials

Tecnifax Corp.—32-page illustrated data book deals with a wide variety of materials and applications which are available to users of the diazotype or whiteprint reproduction process. Light-sensitive papers, cloths and films are described which will produce direct-positive prints of any translucent original, whether written, printed, typed, photographed or drawn.

45. Packing Selector

New York Belting & Packing Co.—Even a layman could pick out the right packing for almost any application in a matter of seconds with a new circular-slide rule type packing selector. Ideal for small users of packings, this free selector contains all the data found in the complete packings catalog. Simple setting yields correct packing for known conditions of equipment and type of service.

46. Centrifugal Castings

Lebanon Steel Foundry—Design, manufacture and final application of centrifugal castings are thoroughly covered in 12-page illustrated brochure. Production facilities as well as details of the Centri-Die and Centri-Spun casting processes are presented in easy-to-use form.

47. Fluid Couplings

Twin Disc Clutch Co.—Complete installation and performance data comprises 14-page illustrated bulletin No. 144-D on fluid couplings. Just how these units can be applied to any type of industrial equipment powered by electric motors or internal combustion engines is shown. Rating range is ⅝ to 850 hp.

48. Corrosion Protection

Allied Research Products, Inc.—Comprehensive file of literature deals with Iridite Chromate Conversion Coatings for prevention of corrosion and paint-base treatment of nonferrous metals. Eight dividers classify data into general information, metal to be treated and finishing processes.

49. Voltage Stabilizers

Raytheon Mfg. Co.—16-page illustrated catalog 4-260 is entitled "Voltage Stabilizers." Described are standard models which meet power requirements ranging from 5 to 2000 watts. They will regulate voltage accurately within ½-per cent in 1/20 of a second.

50. Tachometer-Generator

Servo-Tek Products Co.—Details of a 5 oz permanent-magnet direct-current tachometer-generator are given in 2-page data sheet. This accurate, compact unit serves as a direct-reading tachometer, for synchronizing rotating machinery, as an over or under-speed indicator, as a speed controller and for velocity servos.

51. Fluid Power Equipment

Oilgear Co.—Variable delivery, constant delivery, duplex and automatic feed pumps; constant displacement, Oilgearducers and variable displacement motors; variable speed transmissions; standard and heavy duty cylinders and complete complement of valves and accessories with outputs to 150 hp are detailed in 12-page illustrated bulletin 10051-D.

52. Flexible Couplings

Browning Mfg. Co.—Illustrated supplement V-169-C deals with roller chain type flexible couplings which are available with or without covers. Use of malleable split-taper bushings adapts ten couplings to all bores in range from ⅝ to 3⅞ in. Tabulated are horsepower capacities at speeds up to 3600 rpm.

53. Vibration Control Switch

Beta Corp.—Just how the Vibraswitch, a low-cost vibration responsive device, provides for protection, measurement, warning and automatic shut-down of equipment is outlined in 4-page illustrated bulletin 500-1. This vibration-sensitive switch is adjustable for frequencies from 0 to 200 cycles per second.

54. Industrial Engines

Chrysler Marine & Industrial Engine Corp.—Models 30 and 31 gasoline industrial engines are available as basic engines, open power units and enclosed power units. These 6-cylinder engines deliver 99 bhp at 3600 rpm. Complete specifications are given in illustrated folder.

55. Velocity Pickups

Consolidated Engineering Corp.—Illustrated data sheets 1545, 1535A, 1546 and 1549 describe four models of velocity pickups which are designed to detect and measure torsional vibrations from a rotating shaft, for vibration monitoring, for measurements of vibration frequency and amplitude and for checking vertical and horizontal vibration.

56. Electric Panel Instruments

DeJUR-Amsco Corp., Electronic Sales Div.—Details, specifications and actual size drawings of 1¾-in. sealed square instruments for front and rear panel mounting are given in 2-page data sheet 152. Line includes direct current microammeters, ammeters and voltmeters and alternating current voltmeters in several ranges.

57. Copper Welding Alloys

Eutectic Welding Alloys Corp.—Five new copper welding alloys for welding and soldering copper and copper alloys are described in 4-page illustrated news sheet No. T182263. Properties, application procedures and other data are given.

58. Industrial Engine

Ford Motor Co.—Specifications, design features and performance characteristics of the Ford "215" 6-cylinder gasoline engine are given in 4-page illustrated bulletin. This 215 cu in. displacement engine delivers 93 bhp at 2800 rpm. Also tabulated are specifications of other 4, 6 and V-8 cylinder engines for industrial power applications.

59. Cork Products & Materials

Dodge Cork Co.—Industrial applications and specifications for natural and composition cork are presented in 4-page illustrated bulletin 6-55. Materials are available in sheet, block and granulated forms.

60. Hydraulic Relief Valves

Fluid Controls, Inc.—Technical data sheets 1.11, 1.141 and 1.142 contain design and application information on pilot type relief valves which are designed to limit pressure accurately in an hydraulic system or part. They are particularly usable on machine tools, mining machinery and materials handling equipment.

61. High Speed Index Tables

Ferguson Machine & Tool Co., Roller Gear Div.—Assembly drawings, tables of load ratings and dimensions of over 150 models of Intermittor standard precision index tables for high speed production are found in 12-page catalog 300. They are made with from 4 to 36 work stations and 12 to 48-in. dial sizes. Production speeds of 30,000 pieces per hour are attained on some units.

62 Hydraulic Fluid

Monsanto Chemical Co., Organic Chemicals Div.—20-page booklet contains a step-by-step check list for converting a hydraulic system to Pydraul F-9, a fire-resistant industrial hydraulic fluid. Properties and performance data are included. Fluid has good lubricity, high stability and noncorrosiveness.

63. Sprayed-On Heating Elements

Electrofilm, Inc.—Answers for solution of difficult heating problems due to odd contour shapes, space or weight limitations, lagging, etc., are compiled in file folder "Heating Elements Engineered to Your Design." Technical data are presented on the sprayed on film type heating elements.

64. Testing of Components

General Testing Laboratories—"Assure Reliability by Qualification" is a 4-page illustrated folder that outlines research and development and qualification types of environmental testing carried on by this company. Electronic and electro-mechanical components can be given wide range of tests.

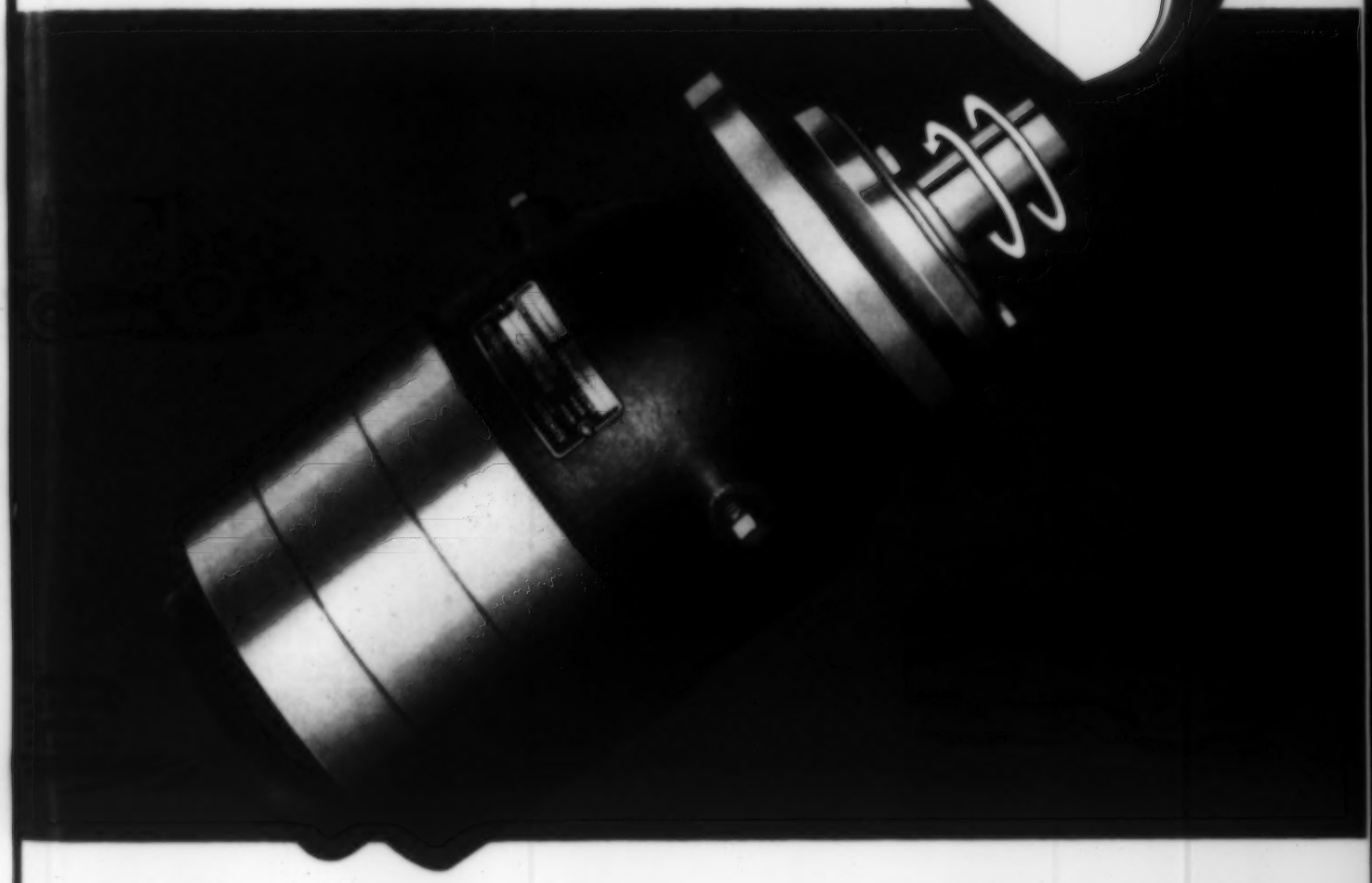
65. Aluminum Bronzes

WW Alloys, Inc.—Properties of 18 grades of aluminum bronzes are given in technical data bulletin 15.100. Chemical composition, tensile and yield strengths, elongation, reduction in area and hardness are given. Centrifugal, permanent mold and sand casting are available. Some grades are available in forging and wrought forms and several are heat treatable.

66. Printed Circuits & Wiring Devices

U. S. Engineering Co.—Useco terminals, terminal boards, and etched and printed circuits are subject of 8-page illustrated bulletin. Facilities of this company to produce and control quality of precision electronic components are described.

Here's how you can simplify power transmission with SUNDSTRAND Fluid Motors...



Sundstrand Fluid Motors provide driving power by converting pressurized oil to rotary motion through a simple wobbler-piston arrangement. With motors as a source of power, you can eliminate complicated mechanical-type transmissions, which are highly subject to wear and require considerable maintenance. The fluid motor is compact, it can be mounted close to the driven member. This does away with gears, clutches, belts, chains, and long shafting. Windup, experience with mechanical-type drives, is no longer a problem. The driven member receives the full force delivered by the high torque motor. Speeds can be controlled infinitely over the complete range of 10 to 1800 rpm without clutching or changing gears. Low starting inertia.

Sundstrand Fluid Motors are simple in design . . . built to withstand rugged treatment. The shaft and wobbler assembly is the only rotating part. Balanced design assures smooth operation and keeps maintenance low. Models range in output up to 30.00 hp at 1000 psi and 1800 rpm. If you have a power transmission problem, a Sundstrand Fluid Motor may be the answer. Get bulletin 113-2 for complete information on application, operation, performance, models, and mounting arrangements of Sundstrand Fluid Motors.

SMALL, COMPACT DESIGN

INFINITE CONTROL OF SPEED

ONLY ONE ROTATING PART

Up to 30.00 hp

SUNDSTRAND MACHINE TOOL CO.
Industrial Division, Rockford, Illinois

SUNDSTRAND

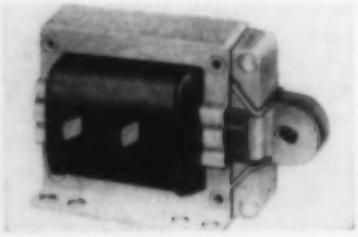
A name to remember in **INDUSTRIAL HYDRAULICS**

NEW PARTS AND MATERIALS

For additional information on these new developments, see Page 229

Small Solenoid

Incorporating new positioning of double shading coil for high seated pull, this small, compact solenoid is especially adapted to rugged duty. The lightweight unit will operate in any position. It is regularly furnished for both constant and intermittent duty,



115-v, 60-cycle ac. Blade terminals are standard; flexible leads are optional. Made by **Dormeyer Industries,** Dept. MDC, 3418 N. Milwaukee Ave., Chicago 41, Ill.

For more data circle MD-67, Page 229

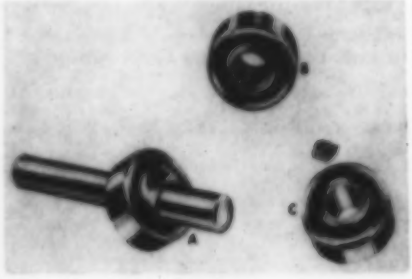
Nylon Fastenings

Nylo - Fast precision - machined nylon fastenings weigh 1/6 as much as stainless steel and ½ as much as comparable aluminum fasteners. Elastic and resilient, they conform to irregular surfaces and lock in place to prevent loosening under vibration. Fasteners have low dielectric constant and relatively high dielectric strength, providing resistance to high voltages. Unaffected by commercial solvents, alcohols, gasoline, oils and boiling 40 per cent caustic soda, they withstand continuous temperatures to 250 F and remain form stable to 450 F. Presently stocked in many of the popular sizes of machine screws and in a variety of colors, the fasteners can be machined to special order and produced in virtually any shade by the Nylatint process. Made by **Anti-Corrosive Metal Products Co. Inc.,** 1233 River Rd., Castleton-on-Hudson, N. Y.

For more data circle MD-65, Page 229

Bearings and Bushings

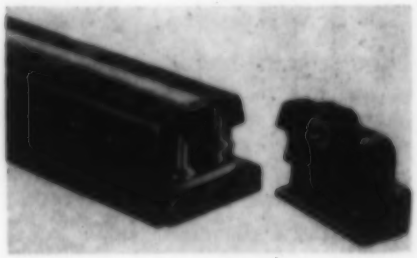
Inner and outer parts of Berco ball-action, self-aligning bearing or bushing are separated by a cushion of molded natural rubber, Buna S, Buna N, Neoprene or silicone rubber. This cushion between the two metal parts of the bearing, combined with the ball-action self-alignment, reduces and absorbs vibration, shock and sound. Tilt of shaft is exaggerated in view A to illustrate the ball action. For rotary motion, needle bearings (B) or a bronze bushing insert (C) can be supplied. Applications of the bearing include use in pillow blocks for line shafts, on electric motors and many other rotating or reciprocating parts requiring self-alignment, noise reduction and shock absorption. Made by **A. J. Berna Co.,** 20160 Sherwood Ave., Detroit 34, Mich.



For more data circle MD-69, Page 229

Sectional Terminal Block

Any number of circuit sections can be securely assembled from three basic parts into this compact, 70-amp, 750-v sectional terminal block. Sections, 1⅜ in. high and 1½ in. wide, are of medium-impact phenolic, highly resistant to heat, shock, moisture and solvents.



They withstand temperatures from −65 to 300 F. Pres-Sure-block design incorporates three integrally molded, serrated pins which locate and secure each circuit section by mating with corresponding holes in the adjoining circuit section. No fastening hardware is needed. Tubular-screw, tubular clamp, or strap type contacts are available for stripped or terminal-ended wire within the range of No. 18 through No. 4. All contacts are plated

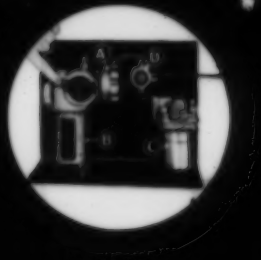
A SIMPLE CONCEPT IN LUBRICATION.

that protects any machine... any bearing surface!

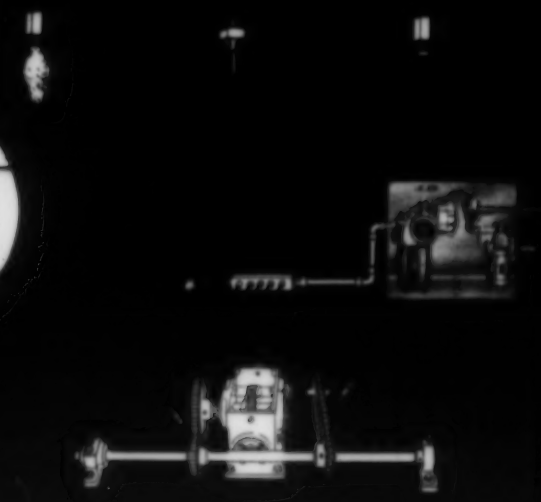
ALEMITE OIL-MIST

here's how it works!

This Oil-Mist lubricator atomizes oil into minute particles which are carried in the air stream through tubing to bearings. Compressed air enters through the air regulator (1) and air gauge (2). As the air passes the venturi (3) it draws oil from the reservoir (4). Oil flow is set by knob (5). The oil-air mixture is thrust against baffle (6), and only the tiniest, lighter-than-air particles are blown through the outlet (7) and through the delivery line to bearings.



Three types of bearing fittings



Complete range of models and multiple unit models—Capacities 12 oz. to one gallon to fit any application!

Alemite Oil-Mist offers these lubrication advantages

Automatic lubrication • Continuous lubrication
Eliminates guesswork • Greater safety • Cuts oil consumption up to 90%
Extends bearing life • Stops oil drippage • Saves man-power
Reduces number of lubricants needed • Eliminates "Down-time"

ALEMITE OIL-MIST LUBRICATION

FREE ... *write today!*

Use coupon below for your free copy of the Oil-Mist catalog and data book!

Alemite, Dept. B-25, 1850 Diversey Parkway, Chicago 14, Illinois

Name

Company

Address

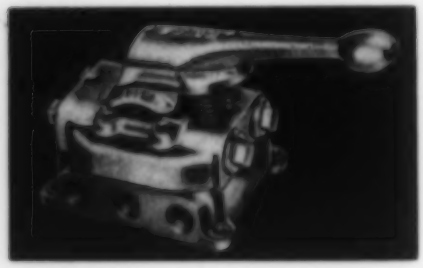
City State

electrolytic copper with positive wire stops. With maximum wire sizes installed in all contact types, contact screws never project above block surface. Pres-fit sections are available factory assembled or in sections for user's assembly with pneumatically or manually operated assembly fixture. Slip-fit sections are available for user's hand assembly and disassembly. Made by **Buchanan Electrical Products Corp.**, 225 Highway 29, Hillside, N. J.

For more data circle MD-70, Page 229

Hand and Foot Valves

Single and double foot treadle and vertical and horizontal hand lever controls are available in improved 880 series of three and four-way valves. Change from hand to

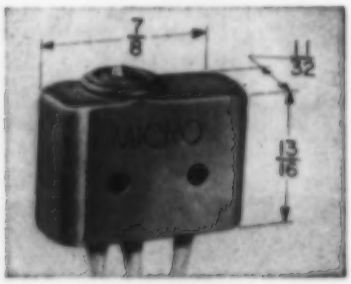


foot operation is easily made. Separate base is provided for bottom or side ports, and an optional base is offered to permit manifolding series of bases to each other for simplified piping. Valves can be disconnected without disturbing piping. All models have standard two-position locking action, but can be ordered with spring return or three-position locking action. Pipe sizes include ¼ and ⅜-in. Pressure rating is 125 psi, and maximum recommended operating temperature is 175 F. Made by **Ross Operating Valve Co.**, Dept. 3101, 120 E. Golden Gate Ave., Detroit 3, Mich.

For more data circle MD-71, Page 229

Sealed Subminiature Switch

Completely sealed model ISEI snap-action switch measures ⅞ x 21/64 x 11/32-in. It operates in the temperature range of −65 to 180 F. Sealing is accomplished with a silicone rubber plunger seal, bonded both to the pin plunger and the metal housing, and by embedment in an epoxy casting resin inside the housing. Exterior housing is corrosion-resistant treated aluminum. Leads, extending out



of the epoxy casting resin, are available in lengths of 1, 3, 5 or 12 ft; special lengths can be ordered. Tentative electrical rating of the switch is 30 v dc, 2.5 amp inductive, 4 amp resistive; maximum inrush is 15 amp. Operating force is 5 to 17 oz; release force, 4 oz minimum; differential travel, 0.004-in. maximum; overtravel, 0.003-in. minimum. Standard contact arrangement is single-pole, double-throw; however, single-pole, single-throw, normally closed and normally open models are available. Minimum mechanical life expectancy of the switch is 300,000 operations. Made by Micro Switch Div., **Minneapolis-Honeywell Regulator Co.**, Freeport, Ill.

For more data circle MD-72, Page 229

Small Motors

High starting torque and exceptional power output are combined in these Barcol YAF unidirectional motors available in three stack thicknesses and nine power ratings from 1/200 to 1/40-hp.

Typical power applications include industrial instruments, fans, small pumps and other devices and appliances. Motors have large oil reservoirs, self aligning oil-impregnated porous bronze bearings, and stainless steel hardened and ground shafts. Various mounting arrangements are offered. Made by **Barber-Colman Co.**, Small Motors Div., 1200 Rock St., Rockford, Ill.

For more data circle MD-73, Page 229

Backstop for Speed Reducer

Shaft-King speed reduction unit is now available with an internal backstop. All except the two smallest sizes of the reducer, in both 13:1 and 20:1 ratio, can be equipped with this safety device, which operates to prevent back-

ward rotation of the unit when the driving torque is removed. Backstop mechanism consists of two case-hardened reversible steel pawls pinned to the high-speed gear; a hardened alloy steel detent, dowelled and bolted to a cover-plate attached to the outer housing of the reducer and furnished with a number of recesses into which the pawls drop when the reducer slows down; and a pair of case-hardened steel, spring-actuated plungers for each pawl, each pair riding in a housing bolted to the high-speed gear. When output speed of the reduction unit exceeds 15 rpm, centrifugal force on the pawls pushes the plungers back into their housings and keeps the pawls out of contact with the de-

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Continental Screw Co.

Manufacturers of Holtite Fastenings

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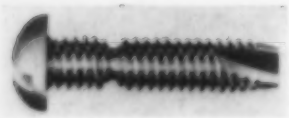
tent. Below 15 rpm the spring pressure forces the pawls into recesses in the detent, assuring locking action. Locking occurs within 1/72 of one backward revolution of the reducer. Made by **American Pulley Co.**, 4200 Wissahickon Ave., Philadelphia 29, Pa.

For more data circle MD-74, Page 229

Break-Off Screw

Attachment of a die-cast piece to another object is simplified through use of this break-off type thread cutting screw which forms a stud in the cored hole of a die-casting. Applications include fastening nameplates and decorative escutcheons of various types. Screw can be hopper fed from power screw drivers. It is driven into the untapped hole until it "bottoms," then

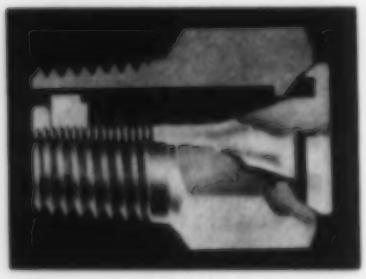


torque is increased and upper portion of the screw, including head, twists off at a "necked down" section. This leaves a protruding stud on which a nut can be threaded. Head portion can be designed for reuse in a different type of application. Made by **Illinois Tool Works**, Shakeproof Div., 2501 N. Keeler Ave., Chicago 39, Ill.

For more data circle MD-75, Page 229

Relief Valve

Pop-off relief valve for pressures from 1 to 125 psi seals tightly with no leakage below release pressure and reseats absolutely tight within 10 per cent of this



value. Sealing is provided by a resilient member fitted into the poppet head which seats into a spherical section in the valve body. When in the closed position, the metal-to-metal seating limits the compressive load on the resilient seal. Spherical valve seat eliminates the need for close stem alignment and close sliding fits in the sealing area. Valve is recommended for applications requiring maximum flow and minimum pressure drop. Made by **James-Pond-Clark**, 2181 E. Foothill Blvd., Pasadena 8, Calif.

For more data circle MD-76, Page 229

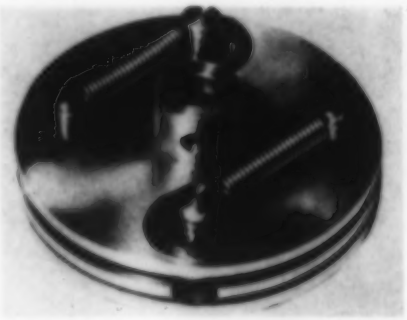
Solids Pump

Operation of this centrifugal type Torque-Flow pump is similar to fluid type torque converter. Although the pump impeller is entirely out of the material flow pattern, it induces a vortex, or swirl, that accomplishes pumping action. Most particles are discharged in less than one revolution due to centrifugal force of vortex action. The rotating fluid mass forms a buffer between the impeller and the solid particles and

chunks in the flow, so that few of them ever touch. Thus, such products as foodstuffs can be pumped without damage. Clogging does not occur, because interior of the pump offers no restriction to flow. Pump has mechanical seals and heavy-duty antifriction bearings which are oil-bath lubricated. Provision is made for rapid disassembly from either end without disturbing piping. Pump handles coarse, abrasive, soft or fibrous materials. Seven models have discharge pipes ranging from 2 to 10 in. in diameter. Capacities range from 200 to 4000 gpm of water at 75 to 100-ft heads. Made by **Western Machinery Co.**, 760 Folsom St., San Francisco 7, Calif.

For more data circle MD-77, Page 229

Precision Coupling

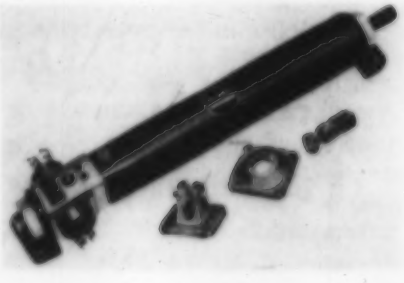


Oldham coupling, designed for medium-speed operation, permits slight angularity and misalignment of two shafts. The unit has a high torque shaft-to-shaft coupling with zero backlash. Coupling is stainless steel throughout. Basic shaft sizes are ⅛, 3/16 and ¼-in. diameter. Stainless steel setscrews for holding and sub-drill holes for fixed pinning are provided, as desired. As many as six different shaft-to-shaft combinations are available. Made by **PIC Design Corp.**, 160 Atlantic Ave., Lynbrook, L. I., N. Y.

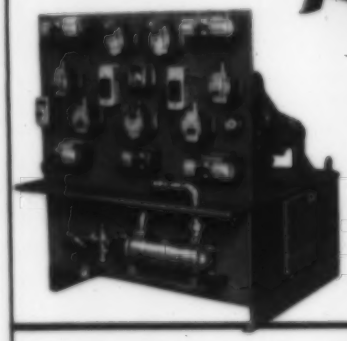
For more data circle MD-78, Page 229

Valve-in-Head Cylinders

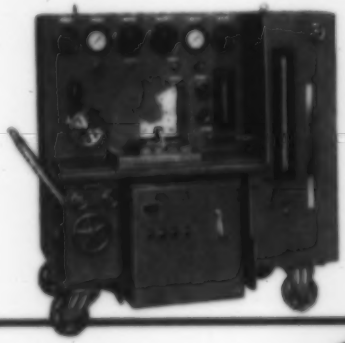
Stroke of any length up to 60 in. and 2 and 3-in. bores are available in Allenair model SVA and SVE valve-in-head cylinders. Made with or without adjustable cush-



Pulpit type power unit provides full visibility, easy accessibility.

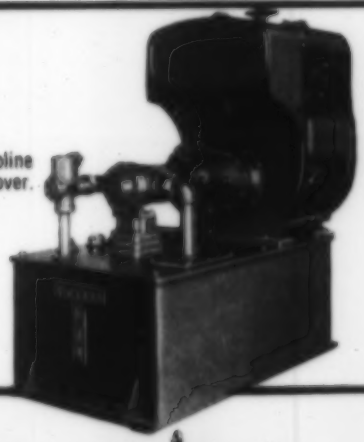


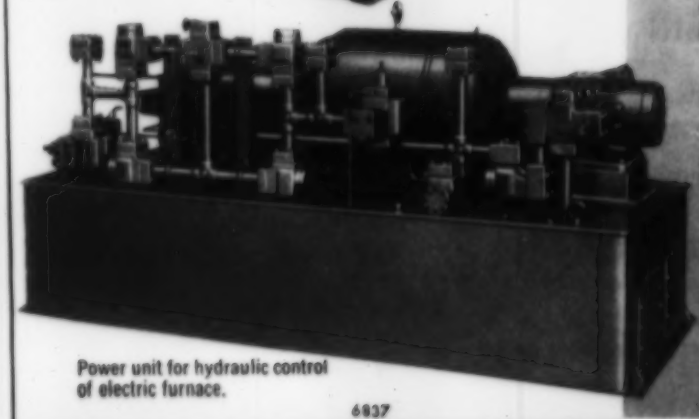
Compact power unit showing gasket-mounted valves.



Portable power unit for testing pumps.

Power unit with gasoline engine as prime mover.





Power unit for hydraulic control of electric furnace.

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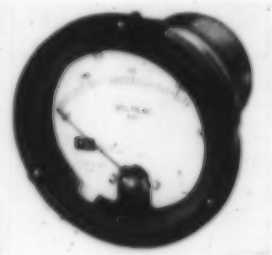
New Parts

ions, they have integral slider type valves in the rear head which are air or electrically operated. Slider is actuated by a spool whose instantaneous motion is achieved by momentarily bleeding air from one end of it or the other. Model SVE, shown, has two control solenoids for 110 or 8-v operation. Two bleeder valves achieve actuation on air-operated unit. Valves have large ports throughout, as well as two built-in speed controls. Foot or flange mounts, swivel brackets and rod clevis are available for mounting in any position. Made by **A. K. Allen Co.**, 57 Meserole Ave., Brooklyn 22, N. Y.

For more data circle MD-79, Page 329

Panel Voltmeter

This expanded-scale panel voltmeter registers ac voltage readings accurately to 0.5-per cent over the frequency range of 50 to 2000 cycles per second. Use of a thermal bridge permits the indication



of a narrow voltage range. The scale is expanded about a given normal voltage which may be as low as 6.25 v with a span of ±0.25 v, or as high as 230 v with a span of ± 30 v. Line includes 3½ and 4½-in. diameter models, as well as 3½-in. square and 4 x 6-in. rectangular models. Made by Arga Div., **Beckman Instruments Inc.**, 220 Pasadena Ave., South Pasadena, Calif.

For more data circle MD-80, Page 329

Miniature Nylon Bearings

Nyliner miniature precision nylon bearings eliminate the need for periodic lubrication, have long life, operate smoothly and silently and

are compact. Gap compensates for substantial dimensional changes which occur in nylon as a result of moisture absorption and temperature variation. Bearings, by running dry, do not collect dust or other contaminants. They are corrosion resistant and can operate in liquids. Mounting bearings directly in a housing bore of recommended diameter saves space, cost and weight. Bearings can be furnished as straight sleeve or flanged type, latter used to take thrust loads or as a means of retention. Either type can be supplied to specific requirements. Made by **Thomson Industries Inc.**, 1029 Plandome Rd., Manhasset, N. Y.

For more data circle MD-81, Page 229

Check Valves

Ball-type Hoke check valves with Swagelok ends are designed for minimum flow resistance and to provide positive reverse flow check. Seat material is synthetic rubber, spring is stainless steel, and the

gasket is fiber. Maximum operating temperature is 150 F. Valve is available in brass with a maximum operating pressure of 1000 psi, in stainless steel with maximum operating pressure of 3000 psi, or in other materials. Swagelok ends prevent vibration. The tubing is well supported and not damaged when the fitting is tightened, nor is any torque transmitted from the leakproof end to

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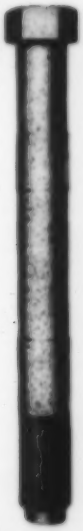

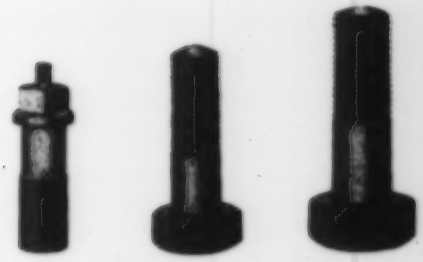

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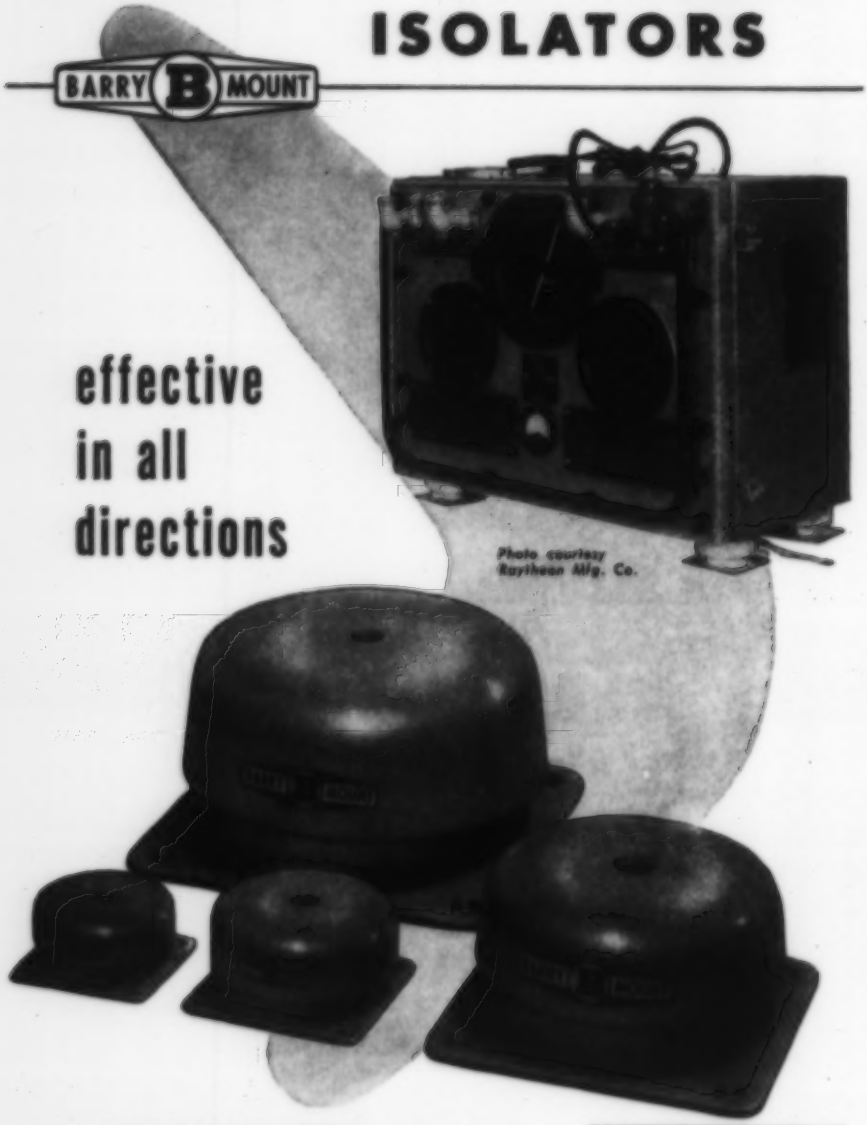

effective in all directions

Photo courtesy Raytheon Mfg. Co.

Type 1000-2000-4000-3000 Barrymounts isolate short-duration shock and high-frequency vibration above 45 cps.

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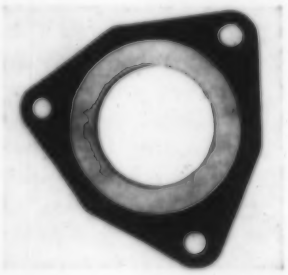
New Parts

the tubing in assembly. Available from **Crawford Fitting Co.**, 884 E. 140th St., Cleveland 10, O.

For more data circle MD-82, Page 229

Ruptureproof Gasket

Danger of gasket rupture at high temperature due to entrapped air between insert and envelope is eliminated by design of Free-Flow Teflon gasket. Inner periphery of gasket does not extend beyond ID of the pipe, and



therefore does not restrict flow or cause turbulence in the line. Envelope is made of chemically inert Teflon, adapting the gasket to all known corrosive services, plus varied temperature conditions from −100 to 482 F, depending upon insert material. Wide variety of shapes and sizes for diverse applications, including glass-lined, porcelain and pyrex equipment, is available. Made by **Crane Packing Co.**, Dept. MDC, 1800 Cuyler Ave., Chicago 13, Ill.

For more data circle MD-83, Page 229

Reinforced Plastic Sheet

Scotchply reinforced plastic consists of one or more sheets of plastic integrally reinforced with continuous glass filaments. Filaments and curing agent are uniformly dispersed, and the filaments are aligned straight and parallel without crimp, slack or twist. Each sheet is composed of 60 per cent glass and 40 per cent plastic resin by weight. High strength in just one direction results if glass filaments of all plys run in the same direction; strength in two principal directions is attained by running filaments at the necessary

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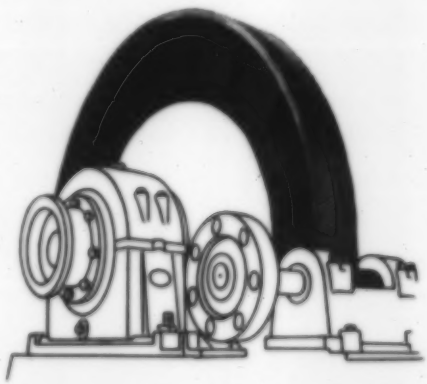
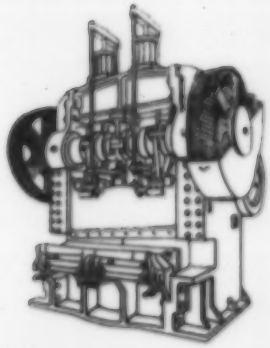
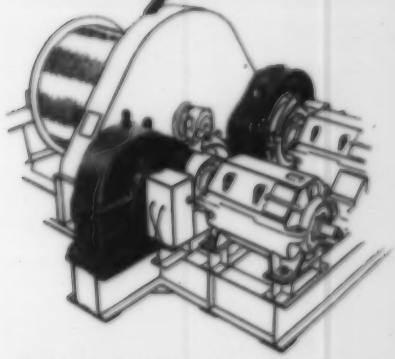


Ball mill equipped with Farrel-Sykes gears.



Shear for cutting mild steel 3" thick by 120" wide.



Skip hoist driven by two motors through Farrel speed reducers.

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angle to each other; and equal strength in all directions is provided if sheets of the material are laminated together at 120-deg angles to produce "isotropic laminate." Tensile strength of this laminate is 41,000 psi; flexure strength, 64,500 psi; compressive strength, 42,000 psi. It is inert to common industrial acid or alkaline atmospheres and salt air. Material is shatterproof, rotproof, mildewproof and waterproof. It can be sawed, sheared, punched, drilled, sanded, painted, cemented and polished. Made by **Minnesota Mining and Mfg. Co.**, St. Paul 6, Minn.

For more data circle MD-84, Page 229

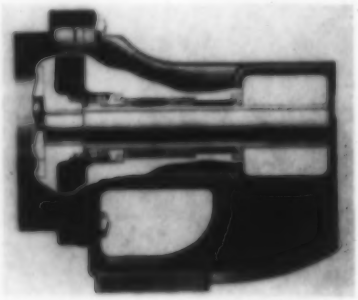
Blower

Small, lightweight blower has a 3-in. tunnel and is rated at 70 cfm at 1 in. of water static pressure. It weighs 20 oz and measures 3⅛ x 3½ x 3⅜ in. long. Compact design affords a large volume of cooling air with minimum external projection. Unit operates directly from a 115-v, 400-cycle line in conjunction with a phasing capacitor. Made by **Servomechanisms Inc.**, Components Div., 625 Main St., Westbury, N. Y.

For more data circle MD-85, Page 229

Liquid Pumps

Mechanical seals now used in Viking heavy and normal duty pumps with capacities from 10 to 300 gpm afford leakless operation and eliminate the need to pack pumps. Seals are offered on unmounted and mounted pumps with

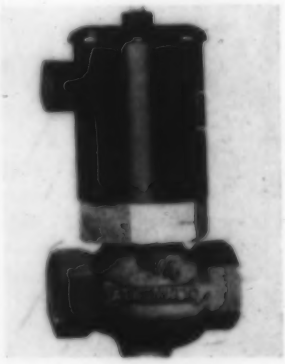


gear, V-belt, direct, double gear, flat belt, or V-belt and gear drives. Heavy-duty pumps are suitable for pressures to 200 psi on lubricating liquids and up to 100 psi on non-lubricating liquids; for similar uses, normal-duty pumps operate at 100 and 50 psi. Carbon graphite bushings which require no external lubrication are used. Seals are made of iron and steel for handling petroleum products or vegetable oils, or of bronze, stainless steel and Ni-resist for water, salt water and brines. Buna N synthetic rubber parts are used in all seals. Made by **Viking Pump Co.**, Cedar Falls, Iowa.

For more data circle MD-86, Page 229

Solenoid Valve

Packless and full-ported semidirect-lift bronze solenoid valve is suitable for use with air, various gases, water, oil, low-pressure steam and other media not harmful to bronze or 316 or 416 stainless steel. When the solenoid is energized, the coil lifts the pilot valve assembly from the pilot valve orifice, thus relieving pressure on the top of the piston. Line pressure then lifts the piston. When there is no line pressure,



the pilot valve assembly engages the piston directly, lifting it from the full port area. Thus, positive opening is assured even at 0 psi. A spring over the piston provides positive closing when the solenoid is de-energized. Valve operates at pressures to 150 psi; at temperatures to 250 F. Sizes are available to fit ½, ¾ and 1-in. pipe. Made by **Atkomatic Valve Co.**, Dept. 1, 545 Abbott St., Indianapolis, Ind.

For more data circle MD-87, Page 229

Remote Control Switch

Bulletin 920 remote control switch is now available with a control line fuse and adapter which may be added to an existing switch

as well as obtained as an integral part of a new switch. Switches are Underwriters' approved to 600 v ac or 250 v dc. Actuation can be by pushbutton, timer, toggle switch or a similar device. Switch is designed for installation on panel boards and switchboards and for separate installation on subpanels. Made by **Automatic Switch Co.**, 391 Lakeside Ave., Orange, N. J.

For more data circle MD-88, Page 229

Linear-Motion Potentiometer

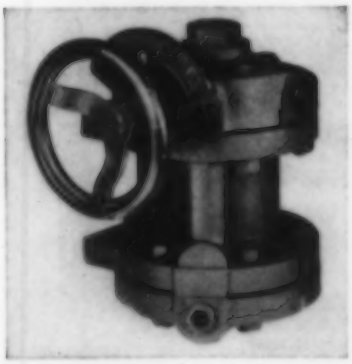
Precision wire-wound Linipot, designed for recording and control instrumentation, accurately translates mechanical position into an electrical signal. Zero-based linear-

ity is ±0.05-per cent with only a 4-in. stroke or shaft displacement. This linearity is attained with a total resistance of 10,000 ohms. Low operating force of 1 oz makes unit suitable for use in servo systems. Resolution factor is less than 0.001-in. Potentiometer has one, two, three or four windings within one case. Individual phasing of windings is ±3/16-in. Resistance range of device is 500 to 50,000 ohms. Made by **Benson-Lehner Corp.**, 2340 Sawtelle Blvd., Los Angeles 64, Calif.

For more data circle MD-89, Page 229

Constant Flow Valves

Flow rate of fuel oil or any other nonabrasive fluid is maintained within 1 per cent up to 200, 300, 400, 500, 600 or 700 gph as desired with new series of constant flow valves. Each model will maintain flow rates as low as 10 per cent of maximum. Flow of fluids with viscosities as high as 250 ssu at operating temperature, static pressures as great as 500 psi and temperatures as high as 250 F can be regulated, despite fluctuations in upstream or downstream pressure. Flow level is accurately maintained as long as viscosity and temperature are constant and pressure differential across the valve is 40 psi



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An opportunity for qualified men to join a company that is steadily growing

A location that offers many advantages

Our Technical Personnel Representative will give you complete details of the opportunities available to men qualified in the following fields:

- Network Theory
- Microwave Technique
- UHF, VHF or SHF Receivers
- Analog Computers
- Digital Computers
- Magnetic Tape Handling Equipment
- Radar and Countermeasures
- Packaging Electronic Equipment
- Pulse Circuitry
- Microwave Filters
- Flight Simulators
- Subminiaturization Techniques
- Electro-Mechanical Design

send complete resume to

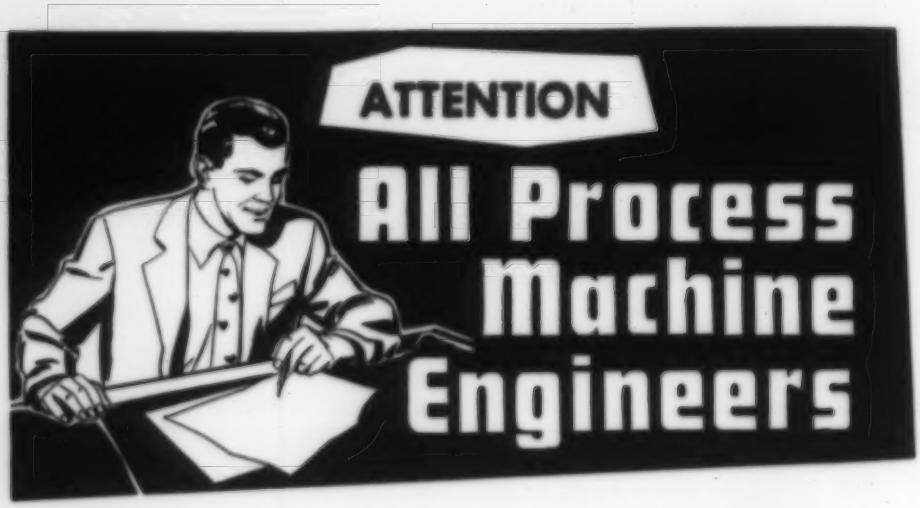
Technical Personnel Representative,

melpar, inc.

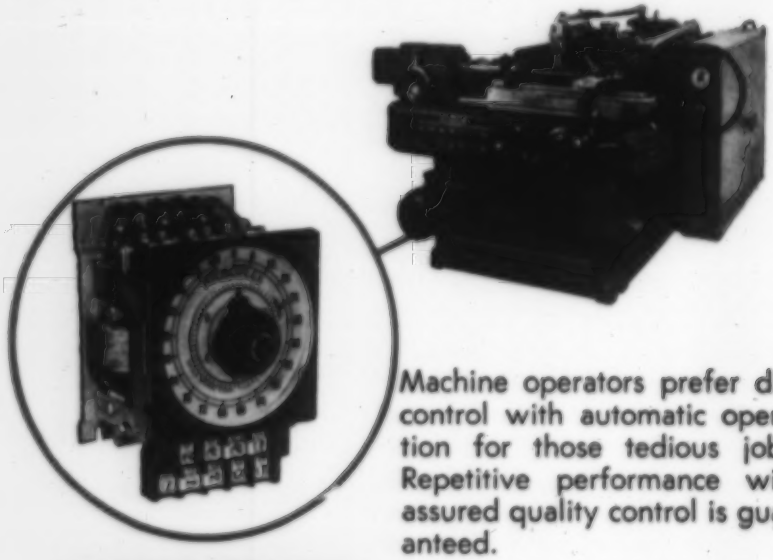
A Subsidiary of the Westinghouse Air Brake Co.

452 Swann Ave., Dept. MD-4 Alexandria, Virgin...

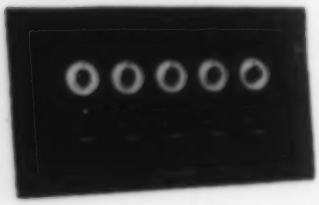
or 11 Galen St., Watertown, Mass.



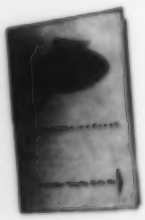
SIMPLIFY YOUR MACHINES AND REDUCE YOUR COSTS BY ADOPTING TIME OR COUNT CONTROL DEVICES.



Machine operators prefer dial control with automatic operation for those tedious jobs. Repetitive performance with assured quality control is guaranteed.



Eagle Signal Corporation can supply a precision timer or counter for any purpose or they can design and build a control panel assembly for your application. Let Eagle engineers assist you with your machine control problem.



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"See What Timing Can Do For You"

Industrial Timers by **EAGLE**

EAGLE SIGNAL CORPORATION
MOLINE, ILL.

Eagle Timers save time, save money.

New Parts

or higher for maximum flow. Flow level can be set manually at the valve or through hydraulic, pneumatic or one of two types of electric remote adjusting systems. These, in turn, can be operated manually or by a pneumatic or electric signal proportional to temperature, flow of another fluid or a gas or some other variable. Made by **Askania Regulator Co.**, 240 E. Ontario St., Chicago 11, Ill.

For more data circle MD-90, Page 229

Pushbutton Switches

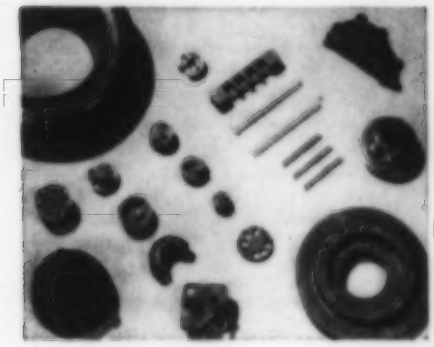
Applicable for control of electronic equipment, appliances, and other assemblies, B1000 series pushbutton switches handle 5-amp resistive loads and 3-amp inductive loads at 115v dc or ac. Precision snap-action mechanism minimizes

arcing and contact wear and provides speedy operation. Copper contacts and terminals have heavy silver overlay. Either lug type terminals or wire leads are available. Molded phenolic housing seals switch from dust and moisture. Threaded aluminum bushing swaged to housing facilitates panel mounting in $\frac{1}{2}$-in. hole. Single-pole single-throw normally open or normally closed contact arrangement is available. Made by **Hetherington Inc.**, Sharon Hill, Pa.

For more data circle MD-91, Page 229

Molding Compound

Glass-filled silicone compound 301 facilitates molding of high-temperature plastic parts. Properly molded parts will withstand continuous exposure to 450 F, intermittent exposure to 700 F. Tensile strength after molding 10 minutes at 340 F is 5000 to 7000 psi, compressive strength is 10,000 to 12,000 psi, and impact strength is 15 to 22 lb-ft per in. Flexural strength

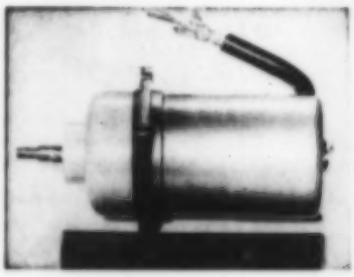


ranges from 12,000 to 14,000 psi at room temperature and 5000 psi at 392 F. Compound can be molded with conventional equipment, and finished parts can be machined with high-speed tools. Mold shrinkage ranges from 0 to 0.0035 per cent. Developed by **Dow Corning Corp.**, Midland, Mich.

For more data circle MD-92, Page 229

Miniature Motor

This permanent-magnet motor, when equipped with a new type gear train that reduces as much as 1600 to 1, can be used in place of a motor several times its size. It is available in six different models with or without gear reduction units. Motor operates with a smaller air gap than is customary



without any deterioration of commutation and without increasing the loss in field shoes. Specially shaped and laminated field shoes are used, and commutators are insulated with mica. Use of extra large brushes provides long life, good commutation, low RF noise and high output. Armature laminations have seven slots and are skewed full slot to assist commutation and to minimize changes in magnetic reluctance. Modifica-

(*Continued on Page 256*)

To label and package drugs for safe, effective use . . .

SHARP & DOHME needs good packaging machinery . . .

and this is the camera that helps them design it

It's the camera that has helped John Deere build a better beet harvester, Firestone make a safer tire, A. B. Dick meet a tight production schedule, Friden figure faster, Michigan Tool roll and sell a better spline.

The Kodak High Speed Camera does this by taking up to 3200 pictures a second on 16mm movie film. Projecting the film at normal speed slows down parts moving too fast for human eyes to follow—slows the action down as much as 200 times to a highly detailed crawl on the screen. The cause of trouble and often the cure stick out like a sore thumb.

Can the Kodak High Speed Camera solve problems for you? Find out by sending for a copy of the booklet, "High Speed Motion Picture Making in Industry."

Graphic Reproduction Division
EASTMAN KODAK COMPANY, Rochester 4, N. Y.

the Kodak *HIGH SPEED* Camera

Kodak

EIGHT WAYS TO GET VARIABLE SPEED

Mechanical

Where moderate speed range is required and where machine may be stopped to make speed changes. Horsepower range—1½ to 300. Speed adjustment range—9 to 28 percent. Two *Vari-Pitch* sheaves used together double range of adjustment.

Combination starter

Squirrel-cage motor

Vari-Pitch stationary control drive

Mechanical

Where infrequent change of speed in low horsepower drives is required and machine may be stopped for speed adjustment. Especially suitable for fan drives, stokers, small pumps and tools. Horsepower range—fractional to 4 hp. Speed adjustment range—18 to 50 percent. Use of two adjustable sheaves doubles speed adjustment range.

Across-the-line starter

Squirrel-cage motor

Texrope adjustable drive

Electrical

Where stepped speed control is satisfactory. Available with stepless control in larger sizes by using liquid rheostat. Speed is varied by means of control on secondary windings of motor. Horsepower range—5 hp and up. Speed adjustment range—50 percent of synchronous speed to full load speed.

Wound-rotor motor control

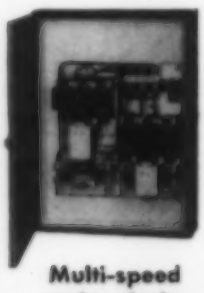
Wound-rotor motor

Texrope V-belt drive

Electrical

Where a few definite speeds are required. Up to four speeds available from one motor. Motor is built on standard squirrel-cage frame with special windings and control. Furnished for variable torque, constant torque and constant horsepower. Horsepower range—½ hp up.

Texrope and *Vari-Pitch* are Allis-Chalmers trademarks.



Multi-speed motor starter

Multi-speed squirrel-cage motor

Texrope V-belt drive

Write for Engineering Literature

A-C ALLIS CHALMERS

ALLIS-

Mechanical

Where speed must be changed while machine is in motion. Particularly good for machines requiring fine adjustment while operating. Double range of adjustment may be obtained by using two *Vari-Pitch* sheaves. Horsepower range—1½ to 600. Speed adjustment range—9 to 28 percent with one *Vari-Pitch* sheave.

Reduced voltage starter | Squirrel-cage motor | *Vari-Pitch* motion control drive

Mechanical

Where very wide range speed control is required or where enclosed unit is desired. May be manually or remotely controlled. Motor may be mounted on speed changer housing for compact installation. Horsepower range—1½ to 75. Speed adjustment range—3¼ to 1.

Across-the-line starter | Squirrel-cage motor | *Vari-Pitch* speed changer

COMPLETE DRIVES from One Reliable Source

Electrical

Where great versatility is required. Speed may be varied by various types of control, either stepped or stepless. For both constant and variable torque loads. Horsepower range—¼ hp up. Speed adjustment range—zero to maximum speed. Maximum speed in smaller sizes, 3500 rpm.

Direct current control | Direct current motor | *Texrope* V-belt drive

Combination

Where extremely wide range is required, a combination drive adds the speed control range of the motor to that of the *Vari-Pitch* drive. Hundreds of combinations of any of the above units can be worked out to fit the requirements of a particular design.

Wound-rotor motor control | Wound-rotor motor | *Vari-Pitch* motion control drive

A4523

CHALMERS

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PIONEER
Impeller Pumps

ROLLWAY
Positive Displacement

PUMPS

For Coolants, Lubricants and Abrasive Liquids

0 to 174 gpm

Something More Than Quality and Performance

Rugged dependability and factory-tested performance are only a part of the story behind Pioneer and Rollway pumps.

For 23 years Pioneer has specialized in the design and manufacture of impeller and positive displacement type pumps. This experience led to the development of a complete pump line of over 400 models. The model shown above is one of a complete line of flange-mounted and submergible type pumps which provides strict conformity to J. I. C. standards.

Pioneer pumps offer manufacturers many important advantages, such as the savings effected through the selection of standard pumps to meet custom requirements. Another important consideration in selecting Pioneer pumps is the unusual opportunity for standardization and interchangeability.

Pioneer application engineers will welcome the opportunity to discuss your pump requirements with you.

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PIONEER PUMP DIVISION
DETROIT HARVESTER COMPANY
Sales and Engineering Offices: 14300 Tireman Ave. · Detroit 28, Michigan
Manufacturing Plant: Paris, Kentucky

New Parts

(*Continued from Page 253*)

tions of speed, torque and other performance characteristics can be made to adapt the motor to various uses, and large torque outputs are available for valve and other actuations. Made by **Airquipment Co. Inc.**, 2248 E. 37th St., Los Angeles, Calif.

For more data circle MD-93, Page 229

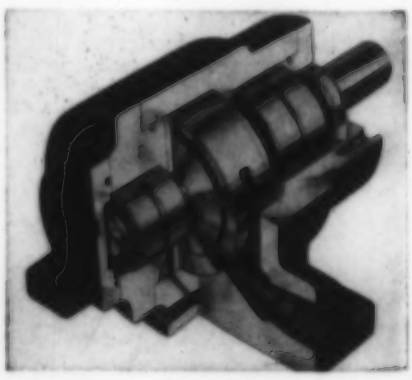
Pressure-Sensitive Tape

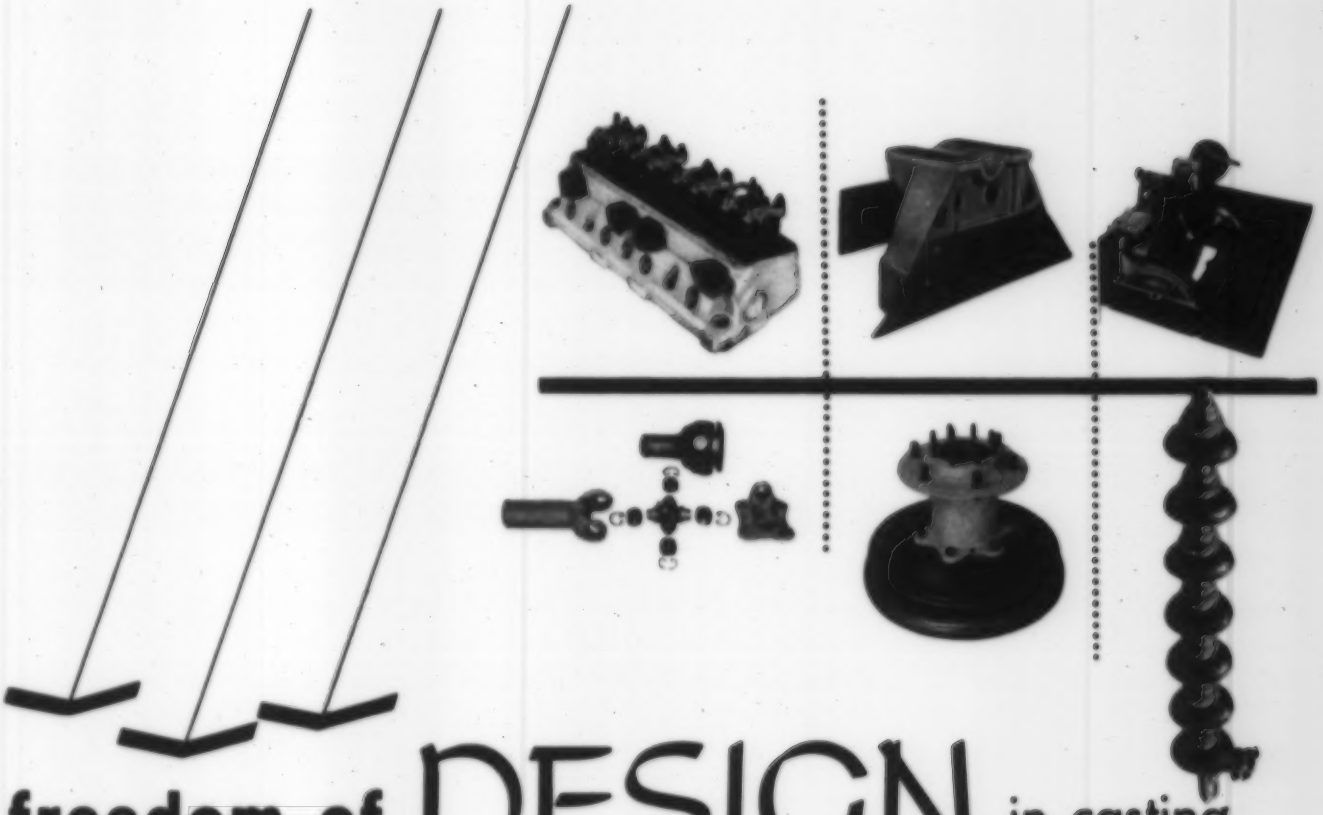
Temp-R-Tape T, made from temperature-stable Teflon coated with a silicone polymer adhesive, can be used at temperatures ranging from −80 to 400 F. It adheres well to plastics, metals, ceramics and most other materials, especially at sub-zero temperatures. As a Class H electrical insulation and for sealing and core wrapping, it will not become brittle, break down or become pasty and loose at elevated temperatures. Made by **Connecticut Hard Rubber Co.**, 407 East St., New Haven 11, Conn.

For more data circle MD-94, Page 229

Fluid Motor

Vane type constant-displacement model C16A fluid motor is designed for continuous operation at pressures to 1500 psi and speeds from 50 to 3500 rpm. Torque is constant at any degree of rotation; running torque is 23.75-lb-in. Bearings will withstand overhung loads equal to full torque on a 6-in. diameter wheel plus a 100-lb external end thrust. Slippage at stall is less than 10 cu in. per





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MALLEABLE IRON CAN BE EASILY **cast** INTO THE INTRICATE SHAPES AND DESIGNS REQUIRED BY MODERN ***HIGH PRODUCTION*** METHODS

We have just one point to make . . . there is no engineering substitute for good, accurate, dependable castings! There is no practical way to put metal where it is wanted . . . so accurately and at so little cost!

. When it comes to the casting of ferritic and pearlitic malleable irons, one name means the most to the men who buy . . . *Albion Malleable Iron* . . . the foundry supplying every major requirement in processes, equipment and service.

Make *malleable* iron, the versatile metal, a part of your product. Contact your *Albion Malleable Iron Company* representative now, he will be glad to bring you up to date on the rapid development in casting techniques and advantages that are yours for the asking.

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with the new "C" Line

WINSMITH SPEED REDUCERS

The all-new "C" Line Speed Reducers by Winsmith offer a host of improved features that simplify your design problems and result in improved performance for your equipment.

By achieving *greater* horsepower and torque output in *less space* "C" Line Speed Reducers allow you to specify smaller units to meet output requirements.

And, this new line furthers the reputation of your equipment thru more rugged performance and dependability.

"C" Line Speed Reducers are available for immediate shipment in 5 sizes within the 1/100 to 5 hp range in a ratio range of 5:1 to 77:1. These 5 sizes are available in each of the models illustrated above. Nine additional sizes available soon. For complete design data on these first 5 sizes request Bulletin CHW-654. Watch for details on our new catalog on the complete "C" line.

WINSMITH, INC.
16 Elton St.
Springville, (Erie County) N. Y.

WINSMITH
SPEED REDUCERS

These features mean improved performance

INCREASED RATED HORSEPOWER AND TORQUE OUTPUT
Diameters have been increased on both the input and output shafts to handle greater loads. Equipped with gears, bearings and shafts rated in accordance with AGMA specifications.

INCREASED OVERHUNG LOAD CAPACITY
Larger, stronger shafts equipped with tapered roller bearings to provide greater capacity and ruggedness.

LONG SERVICE ASSURED
Special nickel phosphor bronze used exclusively in Winsmith Speed Reducers has greater nickel content than bronzes commonly used for gears. It has the greatest strength of all the phosphor bronzes.

ECONOMY
Compare the greater value per horsepower dollar of Winsmith "C" Line Speed Reducers with competitive lines.

New Parts

minute at 1500 psi. Moving parts of motor are precision ground hardened steel. Made by **Racine Hydraulics & Machinery Inc.**, 2000 Albert St., Racine, Wis.

For more data circle MD-95, Page 229

Molded Plastic Valve

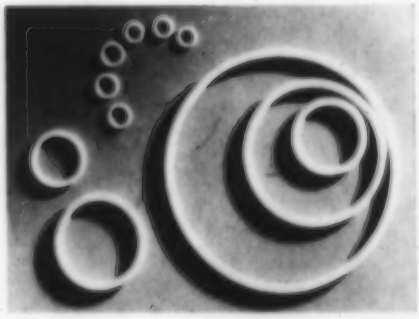
Molded in rigid form, Luncor polyvinyl chloride valve is suitable for pressures up to 125 psi and temperatures up to 150 F. It resists corrosive action of most industrial chemicals. Valve is presently

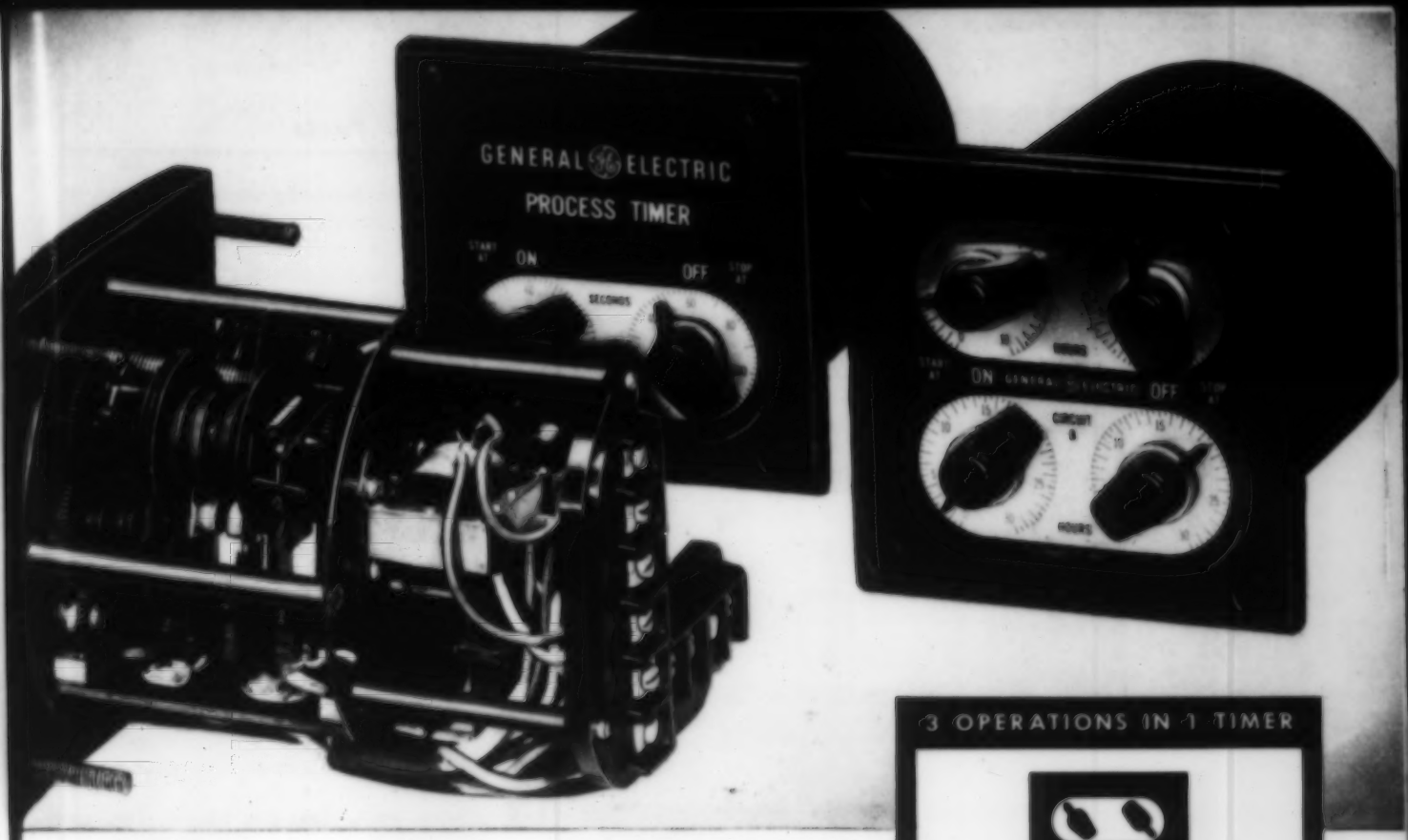
available in Y-type globe design. Also available is complete line of fittings made of same material, including caps, couplings, plugs, unions, reducing bushings, flanges, 45 and 90-deg elbows, and tees. Made by **Lunkenheimer Co.**, P. O. Box 360, Annex Station, Cincinnati 14, O.

For more data circle MD-96, Page 229

O-Rings and Packing

Resistance to chemical attack and high temperatures, plus extremely low coefficient of friction are characteristics combined in Korda Teflon O-rings and packings. They will not contaminate, taste,





NEW G-E TIMER

Cuts Process Timing-equipment Costs

The new General Electric TSA-18 process timer, available in single- and double-circuit models, reduces your need for expensive, custom-built timing equipment. Its adaptability enables it to meet, with precise and dependable operation, the majority of your timing-equipment requirements.

THREE TYPES OF CONTROL are available in the TSA-18. At no extra cost this new process timer is capable of being connected for manual start and reset, automatic reset, and automatic reset and repeat operations.

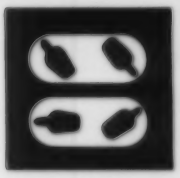
ADJUSTABLE "ON"-"OFF" TIME setting is provided in this new timer. The TSA-18 will begin and end a process at any specified time. Load circuits can be easily adjusted to close or open at any point within this cycle. This feature enables you to reduce the multiple number of timers usually required to perform these timing operations.

HEAVY-DUTY CONSTRUCTION of the TSA-18 reduces maintenance and repair costs and provides long life. Nylon gears, permanently lubricated Telechron* motor, hardened steel parts, and 1/16-inch solid silver-face contacts contribute to the new timer's long life.

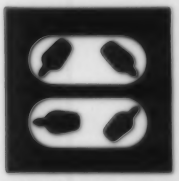
FOR MORE INFORMATION call your nearest General Electric Apparatus Sales Office, or write for Bulletin GEC-1223 to Section 603-179, General Electric Co., Schenectady 5, New York.

*Registered trade-mark, General Electric Co.

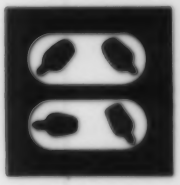
3 OPERATIONS IN 1 TIMER



MANUAL OPERATION
Timer is started and reset manually from an external switch. Two adjustable load circuits independent of each other are available with this type of operation.



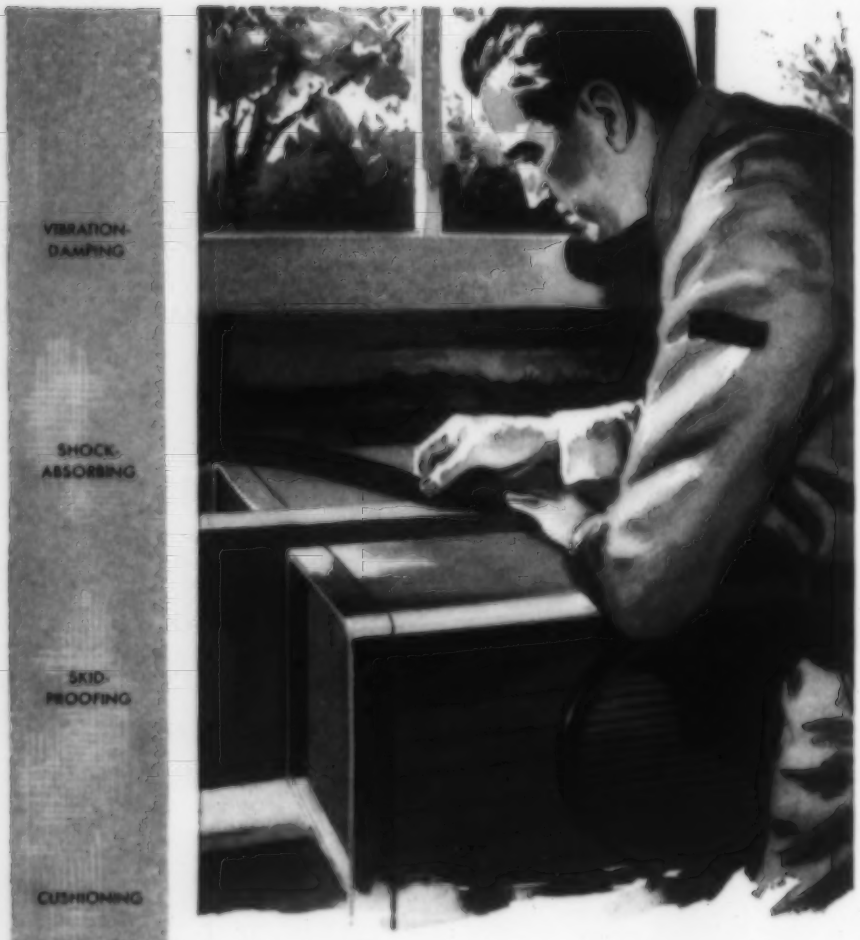
SEMI-AUTOMATIC OPERATION
Timer is started from external switch. Circuit "A" resets time at the end of the adjustable cycle. Circuit "B" opens and closes load circuit within the cycle.



AUTOMATIC OPERATION
Circuit "A" starts and repeats the cycle for continuous operation. Circuit "B" opens and closes load circuit at any point within the cycle.

Progress Is Our Most Important Product

GENERAL ELECTRIC



VIBRATION-DAMPING

SHOCK-ABSORBING

SKID-PROOFING

CUSHIONING

NOISE-KILLING

SCRATCH-PREVENTION

GLAZING STRIP

Noise-killing

It's easy to kill noise and damp vibration with Armstrong DK-153 Tape. This resilient cork-and-sponged rubber material absorbs noise-producing motion between adjacent parts. Pressure-sensitive adhesive backing speeds installation in factory or field. Just peel off protective cloth and press tape into place.

Armstrong DK-153 comes in tapes, rolls, sheets, and die-cut shapes in a wide selection of widths and thicknesses. For samples, write on your letterhead to Armstrong Cork Company, Industrial Division, 7302 Dean Street, Lancaster, Penna. Available for export.

Armstrong DK-153 TAPE

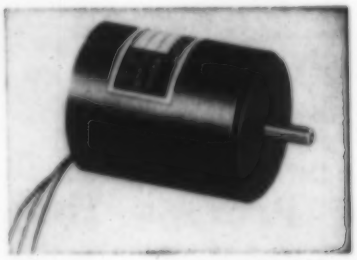
New Parts

odor or coloring of foods, drugs or high purity chemicals. When these O-rings are under compression, total load is distributed over a very small area, resulting in high sealing pressure. When engineered into equipment, the O-rings can seal effectively in both static and dynamic applications. Series 6227 O-ring packing and series 6230 gaskets are equivalent to AN sizes and tolerances. Over 140 sizes are available from ⅛-in. ID to 11 in. OD. Made by **Chicago Gasket Co.**, 1271 W. North Ave., Chicago 22, Ill.

For more data circle MD-97, Page 229

Subminiature Motors

Type SC motors, measuring 1 1/16-in. in diameter, operate at either 400 or 60 cycles ac. They can be wound for single, two or three-phase and can be furnished



as induction or hysteresis types. Characteristics can be modified to cover a wide range of application requirements. Motor can be furnished with a concentric spur gear reducer. Made by **Globe Industries Inc.**, 1784 Stanley Ave., Dayton 4, Ohio.

For more data circle MD-98, Page 229

Nylon-Lined Bearing

Sleeve type Nylacore bearing is composed of a metal shell into which a lining or core of nylon about 0.005-in. thick is molded and rigidly anchored to the outer shell. Tolerances are held as closely as ±0.0002-in. for bore, length, outside diameter and concentricity. Ordinarily no lubrication is required, but such liquids as oil, water, milk and gasoline can be used when necessary. Best bearing life is achieved

if operating temperatures do not exceed 75 to 100 F over room temperature. Over 230 F a lubricant should be provided, while temperatures as low as −100 F require no lubrication. Bearings may be

made with nylon thrust facings, oil seal and dust ring on one end, one end closed, as an integral part of the bearing, or in any combination of these types. Size ranges from as small as 1/32-in. to as large as is practical. Made by **Nylacore Corp.**, Dept. A-1, 305 E. Shore Rd., Great Neck, L. I., N. Y.

For more data circle MD-99, Page 229

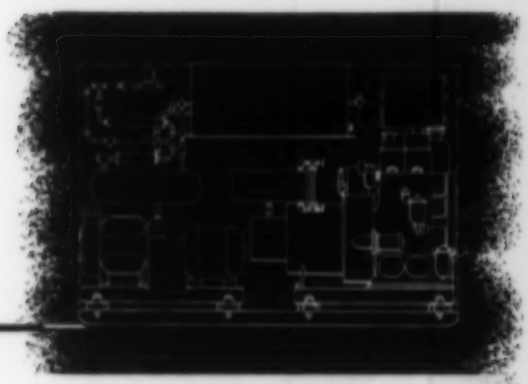
Time Delay Relays

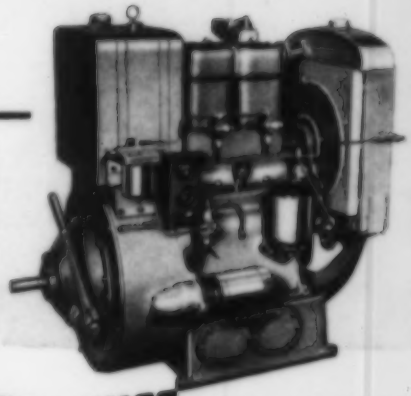
Motor-driven precision adjustable time delay relays are supplied in 2.2-in. diameter housings which are 4.25 in. long. Large calibrated dials with positive detents facilitate rapid and accurate adjustment. Accuracy of time delay function over the calibrated range

of adjustment is ±0.1-second or ±1 per cent of the setting, whichever is greater, over a voltage range of 24 to 29 v dc. Sturdy construction of relay assures operation under severe conditions of vibration, shock and sustained acceleration. Standard electrical

(*Continued on Page* 266)

for a perfect match of Machinery and Power...





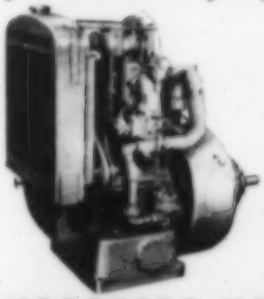
Specify

NORDBERG POWER CHIEF ENGINES!

Why compromise the efficiency of your product to utilize a stock engine when you can get more efficient design with engines built to match your exact requirements?

In the range of 10 to 45 horsepower, or 6 to 30 kilowatts, Nordberg *POWER CHIEF* Diesel Engines can be furnished as both stock engines and as "engineered power packages" with any type of drive, generator, or special equipment you need to assure complete integration of machine and power plant.

Add Nordberg engineering "know-how" to your own to add maximum efficiency and dependable, low cost operation of your product. *Mail coupon for further information.*



NORDBERG POWER CHIEF GAS ENGINES

Nordberg *POWER CHIEF* Spark-Fired Gas Engines provide up to 18 hp, stub shaft or clutch power take-off; and up to 10 kw as "packaged" generator sets. Presently available only as single cylinder units, with 4½" bore x 5¼" stroke.

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NORDBERG MFG. CO., Milwaukee, Wisconsin

NORDBERG

Builders of America's Largest Line of Heavy Duty Diesels

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Nordberg Mfg. Co., Milwaukee, Wis. MD
Please send full details on Nordberg *POWER CHIEF*
☐ Diesel Engines ☐ Spark-Fired Gas Engines
(Check one or both)

Name_____
Company_____
Address_____
City_____ Zone____ State_____

4-155-OEM

Qwik Change

with **PACKAGED Motor Starter PARTS!**

EASY to Identify!

Easy-to-read catalogs, simplified motor control and overload relay selectors, illustrated service bulletins...these all combine to assure *quick changes* through easy parts identification.

EASY to Buy!

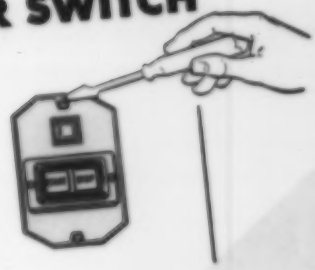
Conveniently packaged and labeled conversion parts are immediately available "off-the-shelf" from a nationwide network of authorized Square D electrical distributors.

Write for Bulletin 9999. Address Square D Company, 4041 North Richards Street, Milwaukee 12, Wisconsin.

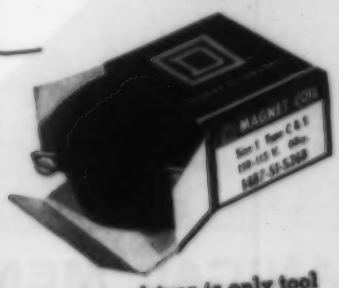
SQUARE D COMPANY

NEW PUSH BUTTONS AND SELECTOR SWITCH

These Kits contain all parts necessary to make quick changes from standard starters to either push button or selector switch controlled devices.



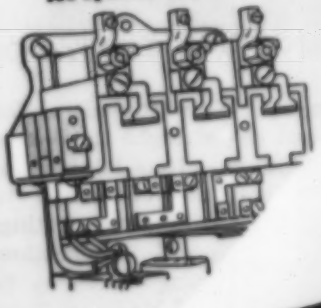
COILS



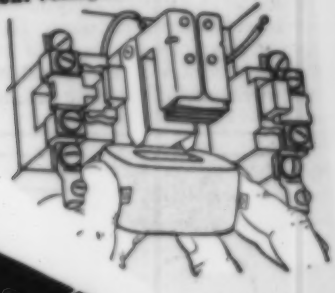
Screwdriver is only tool required for quick change of magnet coil to accommodate different voltages.

INTERLOCKS

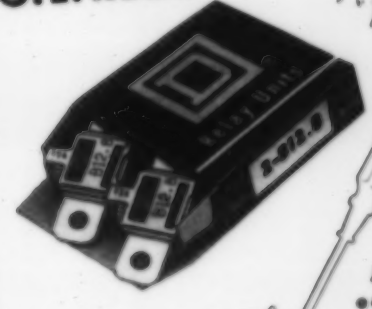
A wide variety of quick-change, front-mounted interlocks adds flexibility for special applications.

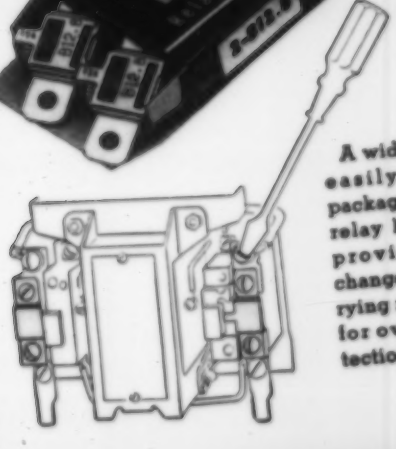


Faster to Install



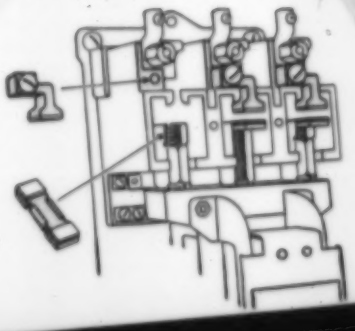
O.L. RELAYS





A wide variety of easily selected, packaged overload relay heater units provides quick changes to meet varying requirements for overload protection.

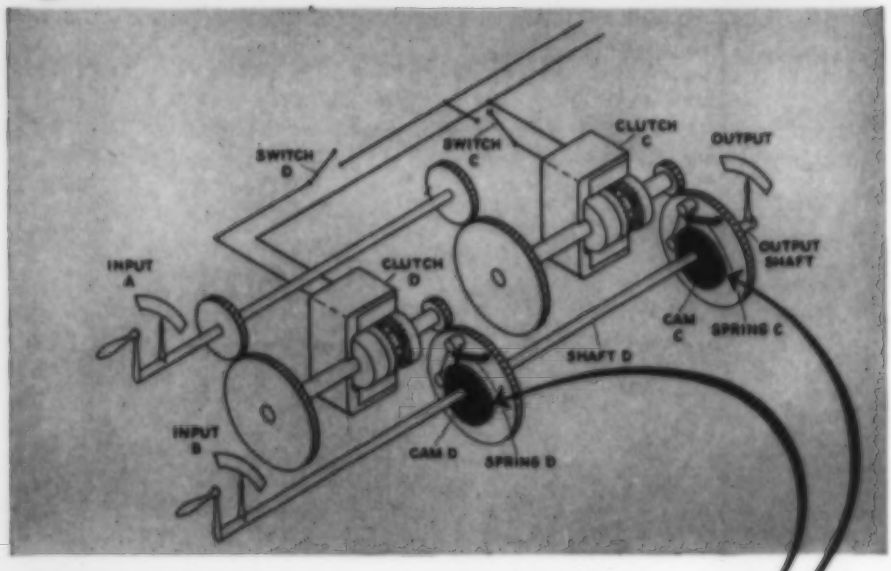
CONTACTS



Packaged replacement contacts are easily installed without disturbing wiring.

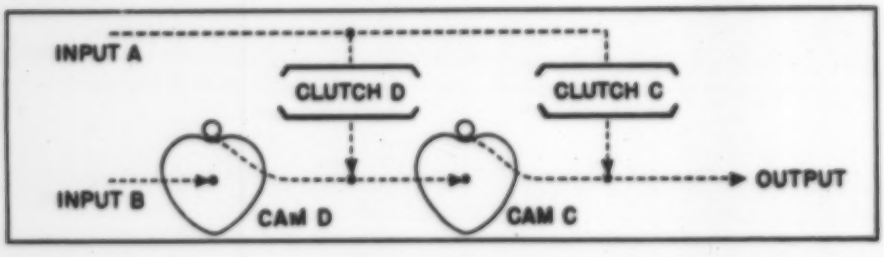
ASK YOUR ELECTRICAL DISTRIBUTOR FOR SQUARE D PRODUCTS

SINCE 1915 LEADERS IN AUTOMATIC CONTROL



MECHANICAL MEMORY with a heart

Ford Instrument Company engineers draw on the entire scope of scientific knowledge to solve each problem. In a recent project, Ford found good use for components it developed a score of years ago to produce a mechanical memory system whose accuracy is independent of the time interval, and which meets a military requirement of absolute reliability.



In an instrument in which the input quantities may vary with time, it is desired to produce an output equal to the change in one quantity A since the time t_1, added to the value that a second quantity B had at time t_1. At the same time it is desired to store another output equal to the change in quantity A since a second time t_2, added to the value that the quantity B had at that time t_2. It is further desired at any subsequent time to be able to read the first output or alternately the second output.

The storing of this information is accomplished by closing clutch C at instant 1 and clutch D at instant 2. The first output is then read directly at any subsequent time and the alternate output by opening clutch C. To recycle – clutch D is then opened.

Whatever problems must be solved in designing and manufacturing computers and controls, skills in electronics, magnetics, hydraulics and mechanical and electrical techniques are called upon by Ford engineers to develop the best instruments for the purpose.

If you have a problem in control engineering, Ford Instrument Company's forty years of experience in high precision design and production will help you find the answer.

46

FORD INSTRUMENT COMPANY
DIVISION OF THE SPERRY CORPORATION
31-10 Thomson Avenue, Long Island City 1, N.Y.

ENGINEERS
of unusual abilities can find a future at FORD INSTRUMENT COMPANY. Write for information.

New Parts

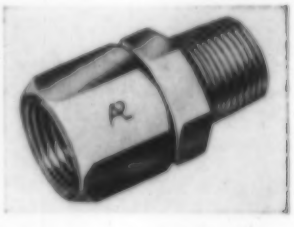
(*Continued from Page 263*)

connection is to screw terminals; solder type terminals can also be supplied. A flange is provided for panel mounting with the dial on the front of the panel. Made by **A. W. Haydon Co.**, 221 W. Elm St., Waterbury 32, Conn.

For more data circle MD-100, Page 229

Pipe Thread Fitting

SFG connector, with a swivel nut on one end and male pipe thread on the other, permits installation where direct mounting of the male pipe thread hose fitting would result in twisting of the hose. Male end of the connector



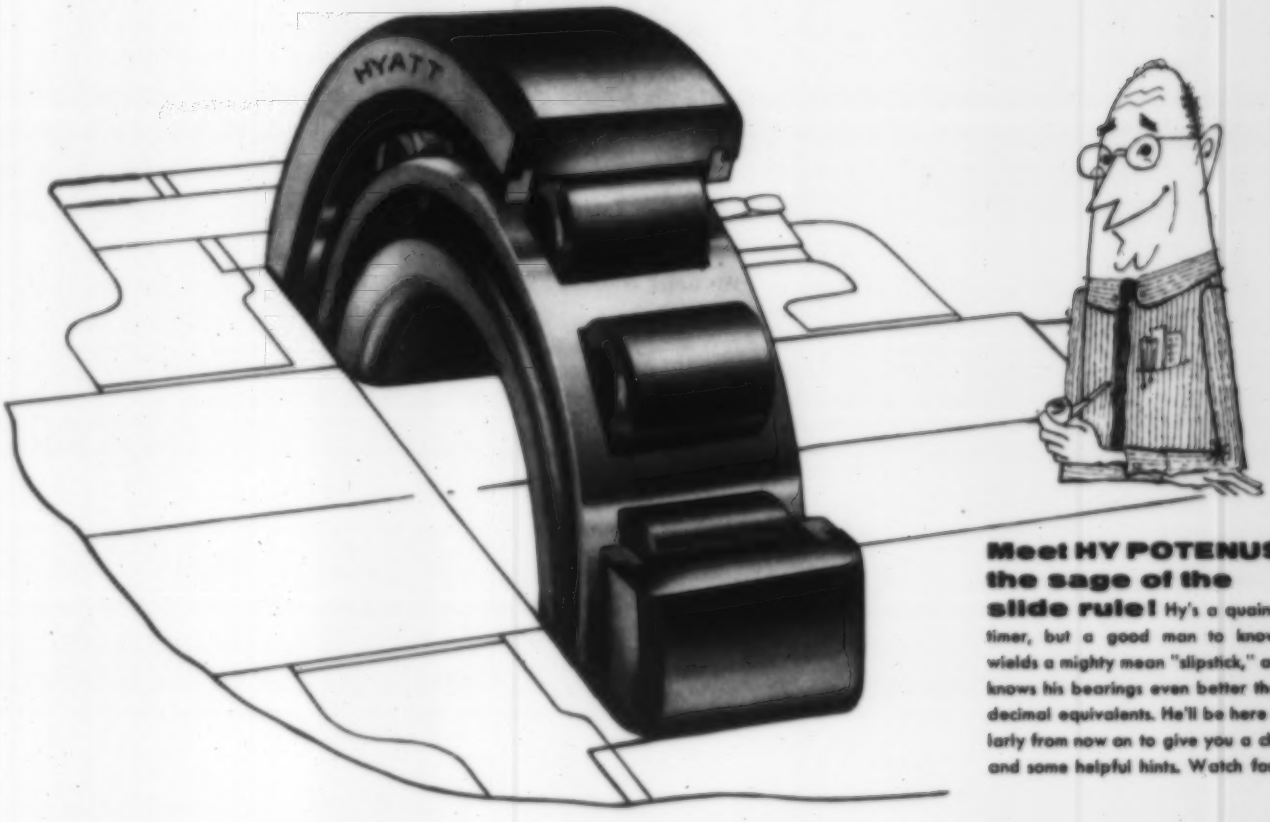
has Dryseal pipe threads. The swivel nut has straight threads to screw onto the Hoze-lok fitting, which is specially chamfered to provide a metal-to-metal seating, assuring leakproof connection. Sizes available range from ⅛ to 2 in. pipe thread. Made by Tube & Hose Fittings Div., **Parker Appliance Co.**, 17325 Euclid Ave., Cleveland 12, O.

For more data circle MD-101, Page 229

Cartridge Thermostat

Expansion of the outer shell of model FM-132 metal thermostat is not necessary to make and break contacts. Thus, mechanical clamping of the cartridge does not affect the set calibration. Although highly sensitive, the thermostat oper-

How Hy-Loads can help you LICK LATERAL SHAFT EXPANSION!



Meet HY POTENUSE, the sage of the slide rule! Hy's a quaint old-timer, but a good man to know. He wields a mighty mean "slipstick," and he knows his bearings even better than his decimal equivalents. He'll be here regularly from now on to give you a chuckle and some helpful hints. Watch for him!

YOUR COMPLETE LINE OF CYLINDRICAL ROLLER BEARINGS

HY SAYS:

Ever stumped by a spot where the shaft heats up and expands laterally—say in an electric motor? You know what happens with laterally locked bearings—you get cramping, misalignment, trouble with a capital T!

But a HYATT Cylindrical Roller Bearing solves all those problems so simply! It allows the shaft to float horizontally—"free lateral," we call it—and automatically compensates for expansion *without changing the bearing centers.* If you haven't a HYATT catalog handy, better send for yours right now. It'll show you exactly which bearing to use where, and help you find the *right* answers to a lot of pesky bearing problems. *Remember, you can't go awry when you specify—*

HYATT ROLLER BEARINGS

STRAIGHT ○ BARREL ○ TAPER ○

HYATT BEARINGS DIVISION • GENERAL MOTORS CORPORATION • HARRISON, NEW JERSEY

NEW

NORGREN MICRO-FOG LUBRICATORS FOR AIR TOOLS AND CYLINDERS

SIMPLIFY YOUR DESIGN PROBLEMS

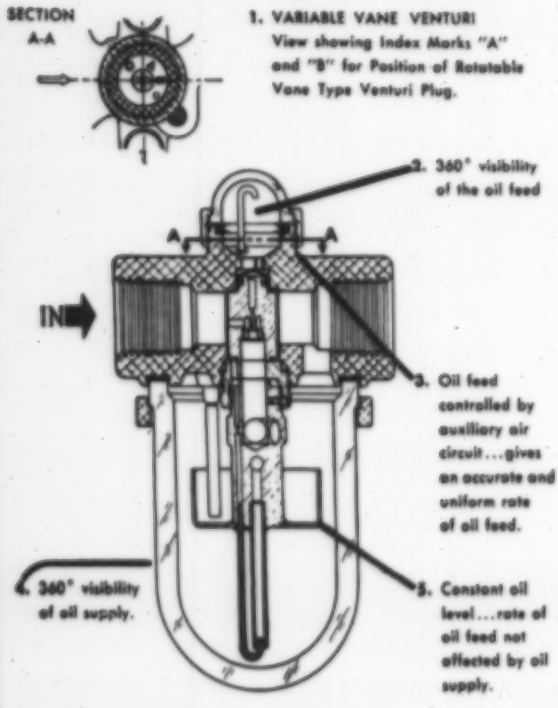
variable vane feature provides greater flexibility

- meet a broader range of operating conditions
- each can handle jobs now done by several sizes of lubricators

A simple adjustment inside the dome provides a wide range of air flow for varying conditions or different applications. For example, at 80 psi the ⅜" size can be set for a flow range of 5 to 9 cfm, a high range of 50 to 100 cfm, or any intermediate range desired.

The new line includes 20 models. Flow capacities: ¼", 5 to 40 cfm; ⅜" & ½", 5 to 100 cfm; ¾" & 1", 5 to 250 cfm. Oil capacities: transparent bowl, ½ pt.; tank type, 1¾ gal. and 4½ gal.

distinctive Norgren features


SECTION A-A
1. VARIABLE VANE VENTURI View showing Index Marks "A" and "B" for Position of Rotatable Vane Type Venturi Plug.
2. 360° visibility of the oil feed
IN
3. Oil feed controlled by auxiliary air circuit...gives an accurate and uniform rate of oil feed.
4. 360° visibility of oil supply.
5. Constant oil level...rate of oil feed not affected by oil supply.
6. Ability to produce a very fine oil fog and deliver it over long distances, through complex piping systems, and obtain equal distribution to multiple lubrication points.

FOR DETAILS WRITE FOR FORM 496

C.A. Norgren CO.
3442 So. Elati, Englewood, Colo.

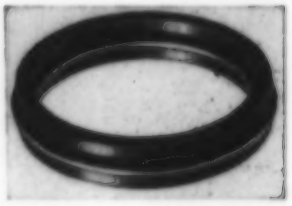
New Parts

ates accurately under severe industrial conditions. Operating ranges available are 0 to 600 F. Unit is rated at 1200 w, 115 or 230 v ac noninductive load. Completely sealed assembly prevents contamination of parts. Calibration is unaffected by vibration. Contacts can be normally open or normally closed; outer shell can be brass, stainless steel or special alloy to meet requirements. Made by **George Ulanet Co.**, 418 Market St., Newark 5, N. J.

For more data circle MD-102, Page 229

High-Pressure Seal

Connealy seal for hydraulic and pneumatic applications fits into a standard groove having the recommended width to accommodate an O-ring and two back-up rings. Sealing is effected by interference



at low pressures, but at high pressures a lip type of seal develops as a result of pressure distortion of the seal. Recommended for difficult high-pressure application, this seal eliminates spiral failures and minimizes seal wear and extrusion. Made by **Sili-Craft Rubber Corp.**, 1700 W. 135th St., Gardena, Calif.

For more data circle MD-103, Page 229

Telephone Type Relay

SQ series miniature, single-coil telephone-type relay is available in 1 to 5-amp contact ratings and in contact combinations from one to six-pole, single or double-throw. Relay offers a maximum sensitivity of 15 milliwatts per pole in the double-pole, double-throw combination, this being an optimum combination which withstands 10 *g* vibration from 10 to 500 cycles. Beryllium-copper armature retaining spring provides positive contact

HOW Norgren Spray-Lube System CAN SIMPLIFY DESIGN OF MACHINE TOOLS

and provide many profitable advantages for users

FOR EXAMPLE

A-P CONTROLS CORP.

Machine taps 12 holes of various sizes simultaneously. Norgren Spray-Lube System includes 5 gal. tank, 12 mixing valves and spray nozzles. Air and liquid line pressures are 42 psi and 44 psi, respectively.

installed Spray-Lube on tapping machine...

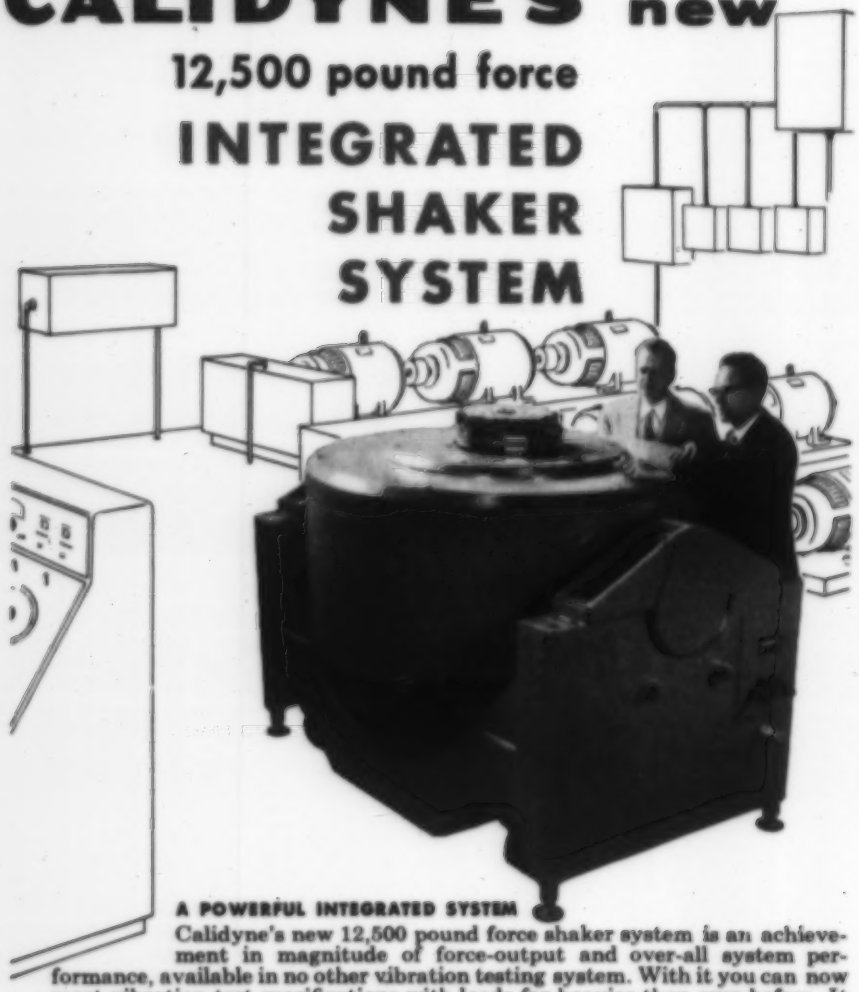
- increased tap life
- increased tapping speed
- eliminated problem of chips plugging coolant lines
- eliminated messy condition of splashing coolant

FOR COMPLETE DETAILS WRITE FOR NORGREN BLUEPRINT No. SL-4

OIL FOG LUBRICATORS • PRESSURE REGULATORS
AIR FILTERS • VALVES • HOSE ASSEMBLIES

C. A. Norgren CO.
3442 So. Elati, Englewood, Colo.

CALIDYNE'S new 12,500 pound force INTEGRATED SHAKER SYSTEM



A POWERFUL INTEGRATED SYSTEM

Calidyne's new 12,500 pound force shaker system is an achievement in magnitude of force-output and over-all system performance, available in no other vibration testing system. With it you can now meet vibration test specifications with loads far heavier than ever before. It also opens new research and product-testing possibilities to commercial manufacturers.

FULL PERFORMANCE OPERATION OVER A WIDE RANGE

Uninterrupted, full rated performance over the 5 to 500 cps range *without* alternator switching or power factor correction results from a new rotary power supply design, which incorporates two identical alternators series-connected with provision for shifting phase between the two outputs. A new ring-type shaker armature suspension assures pure *linear, sinusoidal* motion of the armature system, rather than motion along an arc found in conventional shakers. Useful load is also greater, due to the high force output and light weight armature: 10g with 1000 lb. load, 20g with 375 lb. load.

EXCEPTIONAL STABILITY AND SIMPLIFIED CONTROL

Amplidyne servo controls hold a set frequency of 500 cps to ±1 cps, and displacement or acceleration level to ±3%. The automatic cycling system further provides automatic changeover from constant displacement to constant acceleration at any preselected point, such as required for conformance to MIL-E-5272A. The new power supply design also permits direct connection of alternators to shaker armature. This eliminates control and switch gear, attendant maintenance and inconvenience.

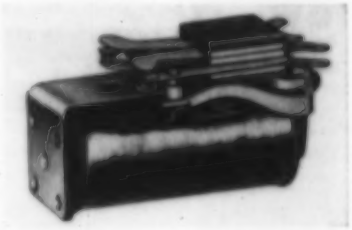
Complete specifications and details on the Model 82 Shaker and Associated System available on request

THE CALIDYNE COMPANY

120 CROSS STREET, WINCHESTER, MASSACHUSETTS

SALES REPRESENTATIVES:
WALTHAM, MASS. Robert A. Waters, Inc. Waltham 5-6900
NEW HAVEN, CONN. Robert A. Waters, Inc. Fulton 7-6700
NEW YORK CITY AREA G. C. Engel & Associates Rector 2-0091
RIDGEWOOD, NEW JERSEY G. C. Engel & Associates Gilbert 4-0870
PHILADELPHIA, PA. G. C. Engel & Associates Chestnut Hill 8-5892
NORTHERN NEW YORK Technical Services Co., Boston Capitol 7-8797
CLEVELAND, OHIO M. P. Odell Co. Prospect 1-6171
DAYTON, OHIO M. P. Odell Co. Oregon 4661
WASHINGTON, D. C. F. E. Jodon, Inc. Woodley 6-2615
SOUTHEAST W. A. Brown & Assoc. Alexandria, Va. Overlook 3-4100
CHICAGO, ILLINOIS Hugh Moreland & Co. Ambassador 2-1555
INDIANAPOLIS, INDIANA Hugh Moreland & Co. Glendale 3803
MINNEAPOLIS, MINN. Hugh Moreland & Co. Colfax 7949
DALLAS, TEXAS John A. Green Co. Diana 9918
HOLLYWOOD, CALIFORNIA G. S. Miller Co. Hollywood 9-6305
SAN FRANCISCO, CALIF. G. S. Miller Lytell 3-3438
ALBUQUERQUE, NEW MEXICO G. S. Miller Co. Albuquerque 5-8656
SEATTLE, WASH. G. S. Miller Co. Lander 3520
CANADA Measurement Engineering Ltd. Arnprior, Ont. Phone 462
EXPORT Rocke International Corp. 13 East 40th St., N. Y. 16, N. Y. Murray Hill 9-0200

New Parts

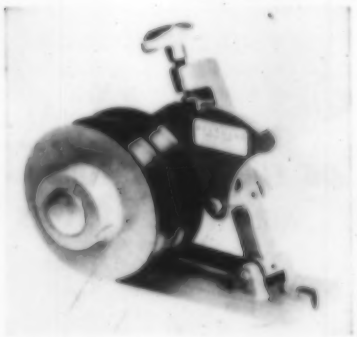


between armature and pivot point at all times. Cross-bar palladium type contacts are always properly aligned. A long nylon bobbin, rigidly fastened to the frame and core assembly by means of a snap ring, permits the selection of many types of wire insulation and also permits winding of any type of coil, including multiple and matched windings. Unit is insulated with silicone glass, Kel-F or Teflon tubing. Movable blades are actuated by ceramic bumpers; nylon or linen-base Bakelite bumpers are optional. Relay measures 1 x ¾ x 1 9/16 in. Double pole, double-throw units are available in a solder-terminal or plug-in type sealed container measuring 1 x 1 x 2 in. Made by **Advance Electric & Relay Co.**, 2435 N. Naomi St., Burbank, Calif.

For more data circle MD-104, Page 229

Variable-Speed Transmission

CUB B variable-speed transmission, designed for applications in the ½ to 1-hp range, uses standard B-section V-belts. Transmission consists of double variable pulleys on a countershaft which can be pivoted laterally between the drive and driven pulleys. This change in center distances adjusts the variable pulleys to new running diameters. Speeds selected are maintained by a handle and locking knob. Pulleys are machined cast



iron and operate on precision ball bearings. Smooth-sided rather than interlocking, both pulleys are on the same side of the mounting frame. The 5-in. pulleys provide a speed range of 3:1 with B-section belts. Overall dimensions of the unit are 8 x 8 x 10 in. high. Made by **Standard Transmission Equipment Co.**, 70 W. Union St., Pasadena 1, Calif.

For more data circle MD-105, Page 229

Small Socket Screws

Complete line of socket head capscrews and setscrews in sizes from No. 4 (0.112-in.) down to No. 0 (0.060-in.) are now available in both 18-8 stainless steel and heat-treated alloy steel. Either hex socket or multiple spline sockets can be obtained, as well as variety of

lengths and threads. Line includes hex socket flat head capscrews, pipe plugs and stripper bolts, in addition to capscrews and setscrews with cone, flat, oval, half-dog, or cup points. Made by **Bristol Co.**, Socket Screw Div., Waterbury 20, Conn.

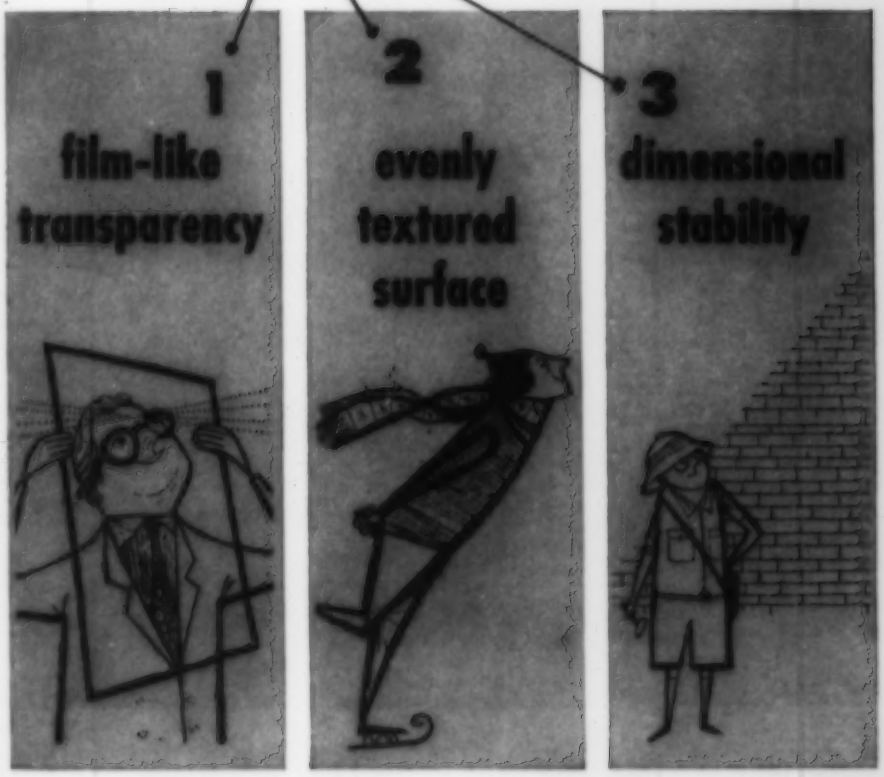
For more data circle MD-106, Page 229

Laminated Pipe

Fluoroflex-T laminated pipe for light-duty use in low-pressure and gravity-feed systems can be used at pressures up to 50 psi. Made of laminated fluorocarbon resins and glass fabric, it handles corrosive liquids at temperatures to 500 F. Pipe is made in lengths up to 12 ft and diameters of 1, 1½

(*Continued on Page 276*)

which tracing medium has all three?



PTM looks like a film and *prints* like a film—no other medium in its price range can approach its transparency! For greater contrast and finer prints, your wisest choice is PTM.

PTM has a flawless, velvety mat surface with complete uniformity in every direction. Erasures leave no ghosts. The glossy back resists dust—keeps your drawings *clean!*

PTM has unusual density to resist atmospheric changes. It is the most stable of all tracing papers; a reliable medium for dependable, close-tolerance drawings!

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POST TRACING MEDIUM

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Send the coupon today for free sample and fact file

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Gentlemen:

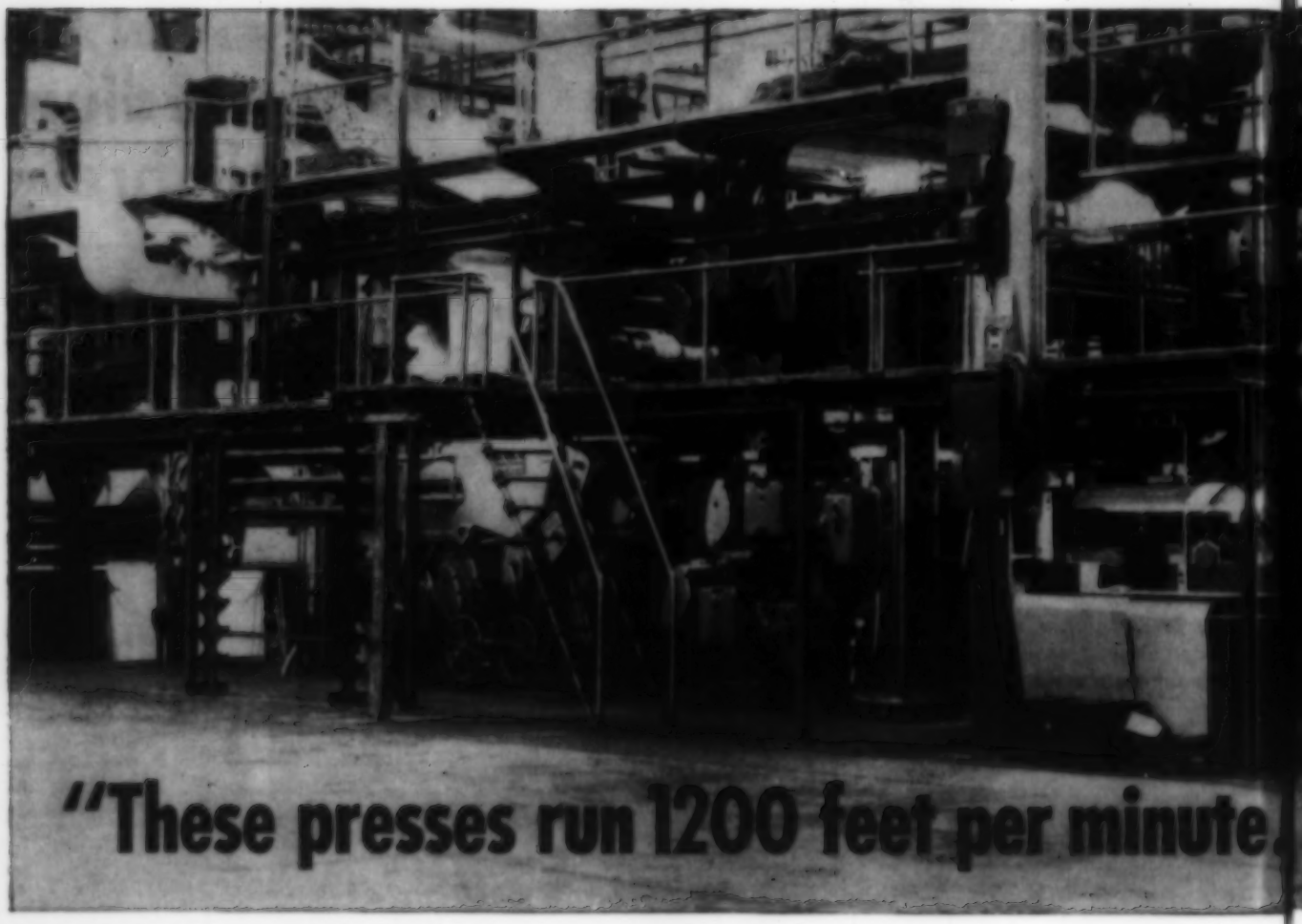
At no obligation to me, please send the "PTM Fact File" with a sample sheet of PTM and price information on various sized rolls and sheets.

Name .....

Address .....

City ..... Zone ..... State .....

Milwaukee • Detroit • Houston • Los Angeles • Englewood



Cutting knife enters the slot visible in these knife assemblies. Springs maintain pressure on the paper during cut.

Here is a giant multicolor magazine press in action.
Paper is cut 640 times per minute.
Press speed: 1200 feet per minute.

so we need springs that can take it"

says Goss Printing Press Company, world's largest manufacturer of newspaper, magazine and rotogravure presses

● 74% of the world's daily newspapers are printed on Goss equipment. Some of the presses are nearly a city block long—giant, roaring machines that gobble up newsprint at the rate of 1200 to 2000 feet per minute. Many of the largest magazines also are printed on Goss presses, which run up to 1200 feet per minute.

At one end of the press is the cutting cylinder, where the paper is cut "on the run." 640 times a minute, the sharp steel knife snaps in and out between two spring loaded fibre "cushions" that hold the paper against the cutting cylinder. When the knife retracts, the springs push the cushions back out of the way.

According to Mr. William Zimmer, Asst. Chief Engineer, "Inferior springs would fail, jam the cutting cylinders, wedge the folding mechanism, and cause severe damage. I don't think that a spring could have a tougher job; but we've been using American Quality Springs for 20 years with excellent results."

American Quality Springs are available in any size, any quantity, any steel, style or finish—including flat wire and special shapes. Just get in touch with your American Steel & Wire representative.

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COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO, PACIFIC COAST DISTRIBUTORS · TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA., SOUTHERN DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS American Quality Springs

USS

UNITED STATES STEEL

YOU NAME IT-

FELT

by FELTERS

will do it...

Filters
Auto parts
Washers
Noise dampeners
Wicks
Packings
Liners
Electrical appliances
Aircraft parts
Shock absorbers
Vibration controls

(Your product goes here)

Resiliency that permits constant spring-back to original shape . . . and good absorptive characteristics . . . are just two of the many properties you can get in Felt made by Felters.

If you have a problem that could be solved by a soft, porous material, or by a hard, dense material — your answer could well be a Felt made by Felters.

The "Felters Design Book" describes several usual and unusual uses for Felt. Drop us a line and we will send you a copy.

HEARD ABOUT **UNISORB®** *— THE MODERN MACHINERY MOUNTING?*

The **FELTERS** Company
218 South Street, Boston 11, Mass.

New Parts

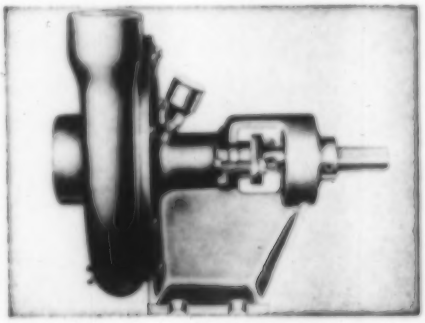
(Continued from Page 273)

and 2 in. Made by **Resistoflex Corp.**, 39 Plansoen St., Belleville 9, N. J.

For more data circle MD-107, Page 229

Centrifugal Pumps

Impeller and shaft assembly is only moving part in these centrifugal pumps, which are available in ½, ¾ and 1-in. discharge pipe sizes. Type H bronze and type C

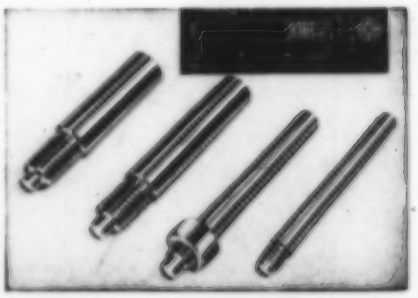


all-iron pumps have sealed ball bearings and semi-open type impeller which permits pumping material containing solids. Made by **E. L. Price Pump Co.**, P. O. Box 357, Sonoma, Calif.

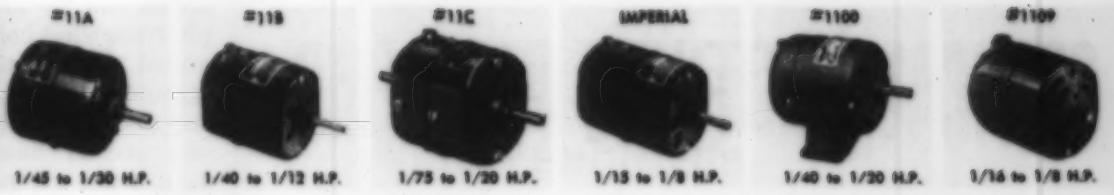
For more data circle MD-108, Page 229

Taper Pins

Threaded-end taper pins can be used as locating or aligning pins or for mounting units which are occasionally removed or replaced. Pins can be used to align motors, pumps or blowers to solid bases, or for aligning component parts of machinery. They will meet any dowel pin or taper pin application involving a blind hole. By turn-



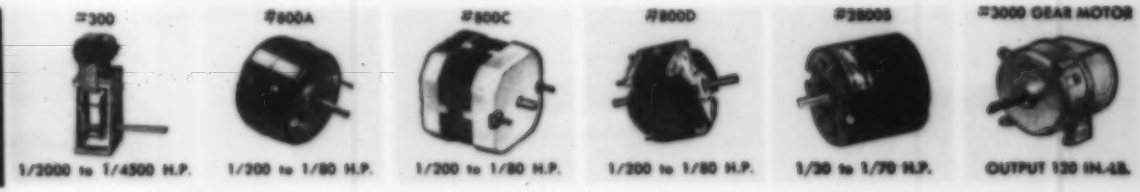
UNIVERSAL AND D.C. MOTORS



THE MOST COMPLETE LINE OF

FRACTIONAL HORSEPOWER MOTORS

SHADED POLE MOTORS



IN THE ENTIRE INDUSTRY...

HOWARD

Universal and Direct Current Motors 1/1000 to 1/2 H.P.
• **Shaded Pole Motors** 1/2000 to 1/8 H.P.
• **Induction Motors** 1/1400 to 1/4 H.P.
• **Dynamotors** • **Blowers** • **Gear Motors**

The motors illustrated on this page represent the versatility of Howard fractional H.P. motors. Catalog pages are available on all motors illustrated as well as gear units, mounting bases and blowers.

If you have a fractional H.P. motor application, check with Howard. Our engineering department will be glad to cooperate with you in selecting the right motor for your application.

Howard motors have been used in more than 85,000 applications over the past 20 years by the leading companies of America.

DEPT. MD-2 • HOWARD INDUSTRIES, INC. • RACINE, WIS.

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SALES OFFICES: 208 S. La Salle St., Chicago 4 • 942 S. La Brea Ave., Los Angeles 36 • Room 4822, Empire State Bldg., New York 1

DIVISIONS: EMC ELECTRIC MOTOR CORPORATION · CYCLOHM MOTOR CORPORATION · RACINE ELECTRIC PRODUCTS

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CRITICAL FASTENING PROBLEMS

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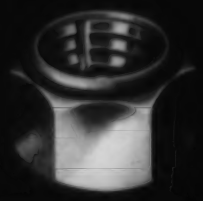
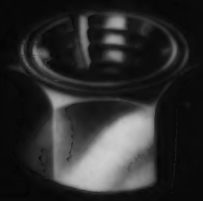
specialized fastening devices

High Temp, Self-locking, Stainless Steel Nuts—Free Spinning On, Lock . . . Unlock, Free Spinning Off—Reusable.



DURA-LOC 1200
(temperatures up to 1200°F.)

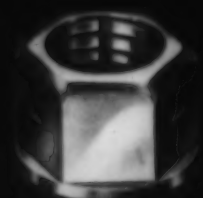


DURA-LOC 1600
(temperatures up to 1600°F.)

High Temp, Stainless Steel Bolts and Screws for temperatures to 1600°F. Special thread form minimizes galling and seizure—Reusable.

DELRON HIGH TEMP BOLT

DELRON HIGH TEMP SCREWS



DELRON # 5 Self-locking, Stop Nut Washer faced. Free Spinning on, lock Free Spinning off after prevailing torque released—Reusable.

FASCO SPACERS Lightweight High Column Strength Aluminum Spacers for assembling and attaching to sandwich-type structural panels.

Illustrated are a few of the many Delron Specialized Fastening Devices designed to help solve your critical fastening problems!

Need data on a specific fastening problem?

THE DELRON COMPANY, INC.

5234 Southern Avenue, South Gate, California

Clip this ad to your letterhead, and mail for product data on items checked: MD

- ☐ Fasteners to 1200°F. operation
- ☐ Fasteners to 1600°F. operation
- ☐ Sandwich structure fastening

Name _____

New Parts

ing nut, or by leverage, jacking action can be applied to remove pin from blind hole. Pins are furnished in any length or diameter, tapered ¼-in. per foot and in various metals with turned or centerless ground finishes. Made by **John Gillen Co. Inc.**, 2554 S. 50th Ave., Cicero 50, Ill.

For more data circle MD-109, Page 229

Process Timer

Repeat cycle process timer that operates continuously to turn circuits on and off for constant interval operation is now offered with percentage timing. Constant accuracy in repeated operation is provided by percentage selection,

and strain on electrical components is reduced. Unit has a time cycle of from 15 seconds to 24 hours, with a range of adjustability for on or off periods up to 94 per cent. Timer has visible dial, snap-action switch with silver contacts, and a synchronous motor. It is 5 in. high, 3 in. wide, 3 in. deep. Made by **Zenith Electric Co.**, Dept. MDC, 152 W. Walton St., Chicago 10, Ill.

For more data circle MD-110, Page 229

Tungsten Carbide Castings

Precision tungsten carbide cast parts for applications involving severe abrasion or erosion are produced on a custom basis. Close tolerances which are held permit use of tungsten carbide castings for

Designing a better "mouse-trap"—or a locomotive—is fundamentally a mental process, the ability to think creatively. This is the basis of all successful design engineering.

- Here, at Morganite, we deliberately let our imaginations soar, then bring them back to earth again with sound judgment and thorough analysis. Following this practice we have uncovered many practical uses for carbon-graphite, aiding in the design of highly efficient, economical industrial equipment and household appliances.
- Carbon-graphite is an inert material resistant to most acids, unaffected by changing temperatures. It is light in weight and will retain it's strength and hardness under extreme temperature conditions. It is self-lubricating, an excellent material for bearings, seals, valves, piston rings, pump vanes and a host of other parts.
- We will welcome an opportunity to work with you. Perhaps together we can solve the "unsolvable." Simply write us, stating your problem. Our technical staff will take it from there.

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A MANUFACTURER OF UNIVERSAL JOINTS SINCE 1919

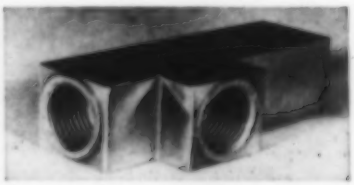
New Parts and Materials

parts such as needle valve points for adjustable chokes, as well as valves and seats in a wide variety of sizes and styles. Corrosion resistant alloys are available. Made by **Carbide Mfg. Co.**, P. O. Box 13125, Houston, Tex.

For more data circle MD-111, Page 229

Automatic Bleeding Valve

For use in all types of hydraulic systems, automatic self-bleeding valve constantly and automatically bleeds air out of the system while it is in operation. Manual bleeding is not necessary, either at the time of installation or

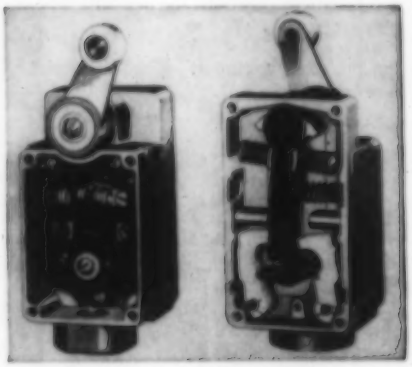


throughout the working life of the system. Valves are connected adjacent to the entrance ports of the hydraulic cylinders. Two valves are required for every double-acting cylinder and one for a single-acting cylinder. Only one is needed, however, for the entire system on hydraulic brakes. Valves are made for all standard size lines and for all pressure ranges. Made by **Radial Metal Products Inc.**, 1044 Linwood St., Brooklyn 8, N. Y.

For more data circle MD-112, Page 229

Limit Switch

Type DM heavy-duty machine limit switch has large wiring space and nylon-to-steel bearing surfaces. Operating arm roller is also nylon. Heavy die-cast housing has an integral solid wall separating mechanical and electrical mechanisms. Ample space is provided for four No. 12 wires. Insulated connectors may be used, but multi-level terminals are provided to permit use of uninsulated pressure type connectors. The overtravel mechanism has two sets of double-concentric coil springs



which permit continuous 30-deg overtravel. Excessive overtravel is accommodated by slippage between mating serrated disks. Conservatively rated at 10 amp continuous capacity up to 600 v ac or 550 v dc, the switch is available with ½ or ¾-in. conduit connections. A variety of front and reverse-lever mounting arrangements can be made with six optional back cover plates. Eight types of operating levers are available, including four lengths of straight levers, and track type, planer type and shipper rod arms. Made by **Clark Controller Co.**, 1146 E. 152nd St., Cleveland 10, O.

For more data circle MD-113, Page 229

Laminated Strip

The corrosion resistance of vinyl plastic and the formability of metal are combined in Marvibond laminated strip. Vinyl sheeting is bonded firmly to steel or aluminum base metal. Available in various colors and in embossed or grained finishes, material is furnished with vinyl sheeting laminated to one or both sides or with the sheeting on one side and a baked-on finish on the other

side. It can be deep drawn, sheared, crimped, bent, embossed, drilled, roll formed and punched without damage to the coating or bond. The vinyl will not chip, crack, craze or flake off. Resistant to acids, alkalies, salt water, alcohol and corrosive liquids and atmospheres, the material withstands weather and humidity indefinitely. It remains dimensionally stable up to 250 F and will not support combustion. Present maximum width of coil strip is 20 in., but the material will soon be made 30 in. wide. Produced under license from United States Rubber Co. by **Enamelstrip Corp.**, Allentown, Pa.

For more data circle MD-114, Page 229

Stroking Diaphragm

Sensater frictionless stroking diaphragm is designed for use in high-pressure hydraulic or pneumatic systems. Its U-shaped annulus rolls when diaphragm strokes. Used for weighing, tension measuring, pressure transmission, controlling, and positioning, unit has high strength and

flexibility and low hysteresis. A 7-in. diaphragm can stroke 5/8-in. and displace 23 cu in. of fluid. Under test, diaphragm completed 250,000 cycles, stroking 5/16-in. at 500 to 600 psi, without sign of failure. Made by **Martin-Decker Corp.**, 3431 Cherry Ave., Long Beach, Calif.

For more data circle MD-115, Page 229

Galvanized-Thread Conduit

Hot-dip galvanized conduit is now available with galvanized threads in sizes ranging from ½

MARVEL *Synclinal* FILTERS

Answers

DESIGNERS S.O.S.

For Dependable Protection on All Hydraulic and Low Pressure Systems

Simple, Balanced Design . . . is the answer to the growing preference for MARVEL Synclinal FILTERS. Designers are specifying Marvel Synclinal Filters to assure minimum maintenance and maximum protection. Results show Marvel Synclinal Filters superiority in maintaining the greatest degree of cleanliness of liquids in all hydraulic and low pressure systems with minimum down-time. Furthermore, when filter servicing is necessary, Marvels can be easily disassembled, cleaned and reassembled by any workman in a matter of minutes. Line types operate in any position and may be serviced without disturbing pipe connections.

Again and again, Marvel Synclinal Filters have demonstrated they meet all requirements of the most exacting users, that today OVER 500 ORIGINAL EQUIPMENT MANUFACTURERS install Marvel Synclinal Filters as standard equipment!

A SIZE FOR EVERY NEED

Available for sump or line installation in capacities from 5 to 100 G.P.M. Greater capacities may be attained by multiple installation (as described in catalog). Choice of monel mesh sizes range from coarse 30 to fine 200.

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FILTERS FOR NON-FLAMMABLE HYDRAULIC FLUIDS

Marvel's most recent development is a filter for the efficient filtration of all types of non-flammable hydraulic fluids.

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Both sump and line type filters have been adapted for use in all water filtering applications. No changes have been made in the basic, balanced synclinal design.

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Phones — Franklin 2-3530 and Franklin 2-4431

COUPON

Without obligation, please send me complete data on Marvel Synclinal Filters, as follows:—

- ☐ Catalog # 195—For Hydraulic Oils, Coolants and Lubricants
- ☐ Catalog # 300—For WATER
- ☐ Data on filters for Non-flammable hydraulic fluids

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MD-2

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2. **Increased Wheel Life** because the shaft is rigidly supported by bearings of ample size.
3. **Super Precision Bearings** made to Pope specifications and used exclusively in Pope Spindles.
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6. **No Additional Lubrication** is ever required. Thirty years of wide factory use has proven the ability of the Pope System of Sealed-in Lubrication to prolong bearing life, reduce maintenance costs and provide cool operation.
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No. 73

POPE MACHINERY CORPORATION
ESTABLISHED 1920
301 RIVER STREET • HAVERHILL, MASSACHUSETTS
BUILDERS OF PRECISION SPINDLES

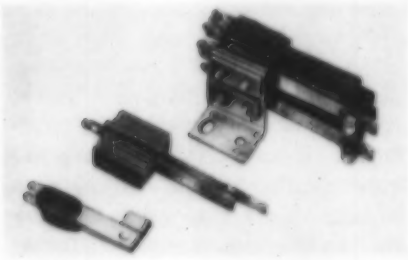
New Parts

through 6 in. Hot-dip galvanizing treatment assures clean, rust-free threads on the zinc-coated conduit. Made by **Pittsburgh Standard Conduit Co.**, 61 Bridge St., Pittsburgh 23, Pa.

For more data circle MD-116, Page 229

Stack Switch Assemblies

Components of these stack switches are variable to meet individual requirements. Spring length, thickness and material are specified by user, as are thickness and size of paper-base phenolic spacers. Contacts can be silver or welded cross-bar Palladium in 3/32, ⅛, 3/16 and ¼-in. diameters; tubing is hard rubber,



Polystyrene or paper-base phenolic; and leaf insulators, punched in same shape as spring, are fish paper or paper-base phenolic. Lifters or pushers of 3/16-in. diameter fiber are available in various lengths; brackets also can be various lengths. Two roller bracket designs are offered for cam followers of nickel plated brass and other materials of various diameters. Mounting hardware can be varied to meet needs. Three typical switches are illustrated. Made by **Switchcraft Inc.**, 1328 N. Halsted St., Chicago 22, Ill.

For more data circle MD-117, Page 229

Vacuum Pump

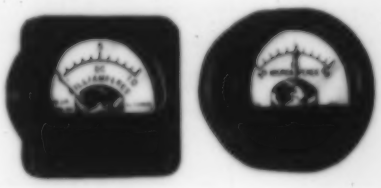
Every movement of the Rite-Way vacuum pump produces vacuum. Suitable for various types of machinery, the pump has off-center core that moves a simple oscillator around the inner edge of the pump wall, constantly taking in air from one side and dis-

charging it from the other. Vacuum is obtained immediately when reciprocating rotor is started. Speed is variable from 560 to 2015 rpm by changing or interchanging drive and driven pulleys. Volume of free air that can be moved within this speed range is 1 to 12 cfm. Pump is available with 1/3 or ½-hp electric motor or 1½-hp gasoline engine. Moving parts are sealed in oil which is kept clean by magnetic drain plug. Made by **Package Machinery Co.**, Springfield, Mass.

For more data circle MD-118, Page 229

Miniature Panel Meters

Two 1½ in. sealed meters are designed for panel mounting. Model 152, left, for front or rear mounting, is sealed by an internal locknut between the instrument mounting flange and case barrel. The locknut compresses a heavy-duty gasket uniformly and concentrically. Terminal studs are sealed similarly. Model 150, right, is made for one-hole mounting without conventional hardware. It



has a Neoprene O-ring panel gasket which provides a positive water-tight seal. Terminal studs are sealed in the same manner. Accuracy of both instruments is within ±3 per cent of full scale. Housings are aluminum or steel.

(*Continued on Page* 290)

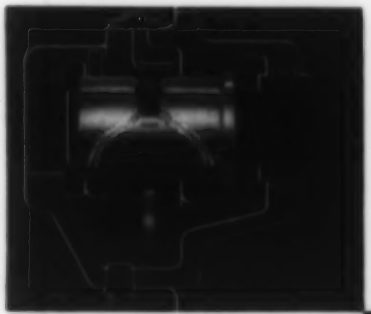
SIMPLE,

low cost housings suffice

FOR BUNTING BEARINGS

The size and weight of parts required to support a bearing sharply affect initial cost and production costs. Because the Bunting Bronze Bearing is much smaller in diameter than other types of bearings required for similar applications, the supporting parts are lighter and lower in cost.

You can easily learn what economies can result from your use of Bunting Bronze Bearings. There is a Bunting engineer near you for consultation. Or write our Product Engineering Department at Toledo.



The weight of parts required to support a bearing varies directly as the square of the outside diameter of the bearing. The Bunting Bronze Bearing is much smaller in outside diameter than other types.

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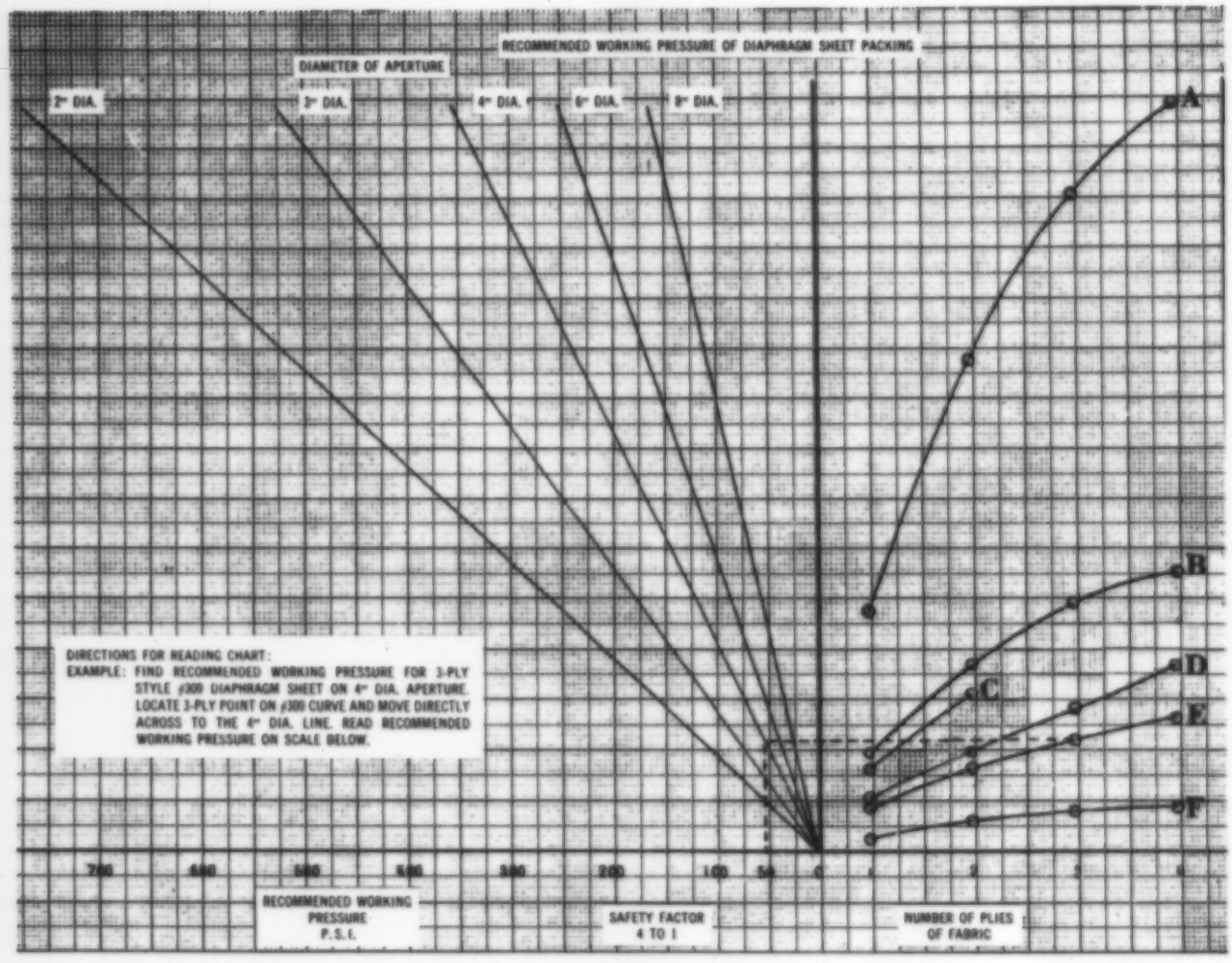
This United States Rubber Company Chart

will help design engineers specify the proper diaphragm sheet packings

This valuable chart shows at a glance the recommended working pressures of the most widely used diaphragm sheets. Crude rubber covers are recommended for water, air, steam and dry natural gases; Neoprene covers for mineral oils; Buna N covers for all services especially where diffusion is a problem. Send for your *free enlarged reproduction*. Write to address below.



A. NYLON-P-2902 (CRUDE RUBBER) P-2903 (BUNA N) P-2904 (NEOPRENE)

B. COTTON-P-2139 (CRUDE RUBBER) P-2141 (NEOPRENE)

C. NYLON-P-2339 (CRUDE RUBBER) P-2341 (BUNA N) P-2905 (NEOPRENE)

D. COTTON-#509 (CRUDE RUBBER) P-2133 (NEOPRENE)

E. COTTON-#309 (CRUDE RUBBER) P-2135 (NEOPRENE)

F. COTTON-P-2136 (CRUDE RUBBER) P-2138 (NEOPRENE) 1516-F (CRUDE RUBBER) P-2335 (BUNA N) P-2901 (NEOPRENE)

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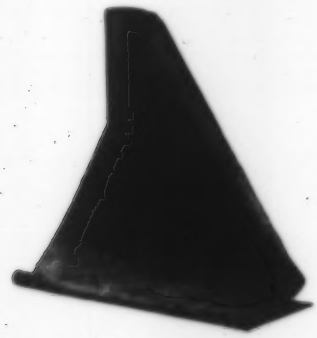
Hydraulic Diaphragm Sheet Packing by U.S. Rubber



U.S. Duck Inserted Diaphragm Sheet Packing

Style No. 309—*crude rubber cover*. General purpose packing, with medium-weight duck inserted between covers of high-grade rubber compound. For packing reducing valves and regulators of all types.

Style No. 509—*crude rubber cover*. Recommended for reducing valves and regulators of all types. High tensile square-woven duck gives structural strength over entire area. Furnished 46″ wide, 1/16″ thick and up.

Style No. P-2133—*Neoprene cover*. Impervious to action of cold oils and gasoline. High-quality medium-weight duck insertion. Furnished 46″ wide, 1/16″ thick and up.

Style No. P-2135—*Neoprene cover*. Oil-resistant, with lightweight duck insertion. Furnished 46″ wide, 1/16″ thick and up.

U.S. Sheeting Inserted Supersensitive Diaphragm Packing

Style No. 1516-F—*crude rubber cover*. Especially recommended for low-pressure conditions where supersensitiveness is essential or desirable. It has exceptional flexibility and is extremely sensitive and responsive to the slightest change in pressure. The bursting strength across a 2″ circular opening in the 1/32″ thickness is about 45 pounds, and in the 1/16″ thickness about 67 pounds, per square inch. Furnished in rolls of 100 and 200 pounds, 36″ wide, in 1/32″, 1/16″, 3/32″, 1/8″ and 3/16″ thickness.

Style No. P-2136—*crude rubber cover*. Has sheeting insertion, in 36″ width only, 1/32″ thick and up.

Style No. P-2138—*Neoprene cover*, with sheeting insertion, in 36″ width only, 1/32″ thick and up.

Style No. P-2335—*Buna N cover* with special sheeting insertion. 36″ wide, 1/32″ thick and up.

Style No. P-2901—*Neoprene cover* with sheeting insertion, recommended for handling oils and solvents; 36″ wide, 1/32″ thick and up.

Style No. P-2139—*crude rubber cover* with extra-heavy duck insertion, 1/8″ thick and up.

Style No. P-2141—*Neoprene cover*. Oil-resistant, with extra-heavy duck insertion, 1/8″ thick and up.

U.S. Nylon Inserted General Service Diaphragm Sheet Packings

Style No. P-2902—*crude rubber cover*. General service diaphragm sheet; supplied in 40″ widths of 1/16″, 1/8″, 3/16″ and 1/4″ thicknesses.

Style No. P-2903—*Buna N cover*. General service diaphragm sheet. Supplied in 40″ widths of 1/16″, 1/8″, 3/16″ and 1/4″ thicknesses.

Style No. P-2904—*Neoprene cover*. General service diaphragm sheet. Supplied in 40″ widths of 1/16″, 1/8″, 3/16″ and 1/4″ thicknesses.

U.S. Nylon Inserted Supersensitive Diaphragm Sheet Packings

recommended for high pressures

Style No. P-2339—*crude rubber cover* with supersensitive diaphragm sheet. Supplied in 36″ widths in 1/32″, 1/16″ and 1/8″ thicknesses.

Style No. P-2341—*Buna N cover*. Supersensitive diaphragm sheet; supplied in 36″ widths of 1/32″, 1/16″ and 1/8″ thicknesses.

Style No. P-2905—*Neoprene cover*. Supersensitive diaphragm sheet; supplied in 36″ widths of 1/32″, 1/16″ and 1/8″ thicknesses.

UNITED STATES RUBBER COMPANY manufactures a complete line of diaphragm sheets for a wide variety of hydraulic service conditions. U. S. Packings and engineering service are obtainable at any of the 27 "U.S." District Sales offices or by writing address below.

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FAIRFIELD MANUFACTURING CO.

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Fine Gears Made to Order

Send for a copy of this illustrated bulletin describing Fairfield's facilities for making gears.

New Parts

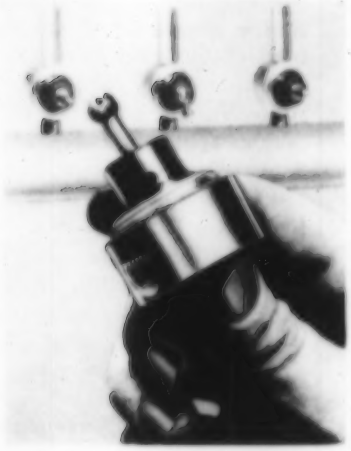
(*Continued from Page* 287)

Zero-left scale is standard; zero-center and zero-right models are available from **DeJur-Amsco Corp.**, 45-01 Northern Blvd., Long Island City 1, N. Y.

For more data circle MD-119, Page 229

Toggle-Actuated Valve

Bronze, aluminum, steel or stainless steel body with Neoprene diaphragm comprise this toggle-actuated Demi valve. Bonnets can be furnished as shown or threaded on the outside for panel mounting. Toggle is hard chrome-plated, case hardened steel. Bonnets may be

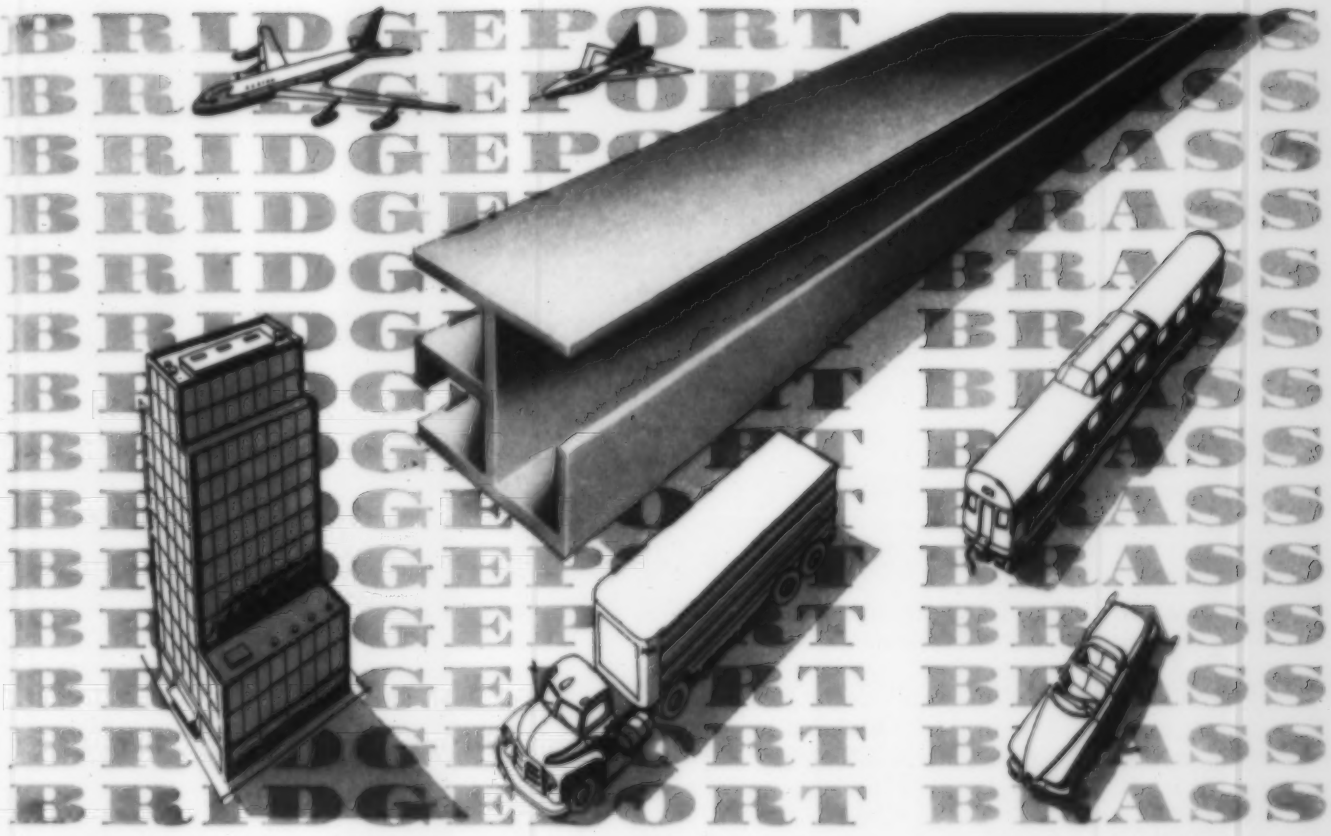


anodized in various colors for coding purposes. Valves are 1½ in. OD, 2 in. high. Currently used on up to 200 psi air, they have been tested on air up to 500 psi. Valve can be furnished in TV-3 model, which is a three-way valve with a vent to the atmosphere. Made by **George W. Dahl Co.**, 430 High St., Bristol, R. I.

For more data circle MD-120, Page 229

Servo Gearmotor

Weighing 4½ oz and measuring 1⅛ in. in diameter and 2 17/64 in. long, this miniature continuous-duty gearmotor operates from an input of 115 v, two-phase, 400-cycle ac. No-load speed is 180 rpm; full-load speed, 135 rpm. Gear reduction is 28.4. Various speed and torque combinations are



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Future-minded designers and manufacturers are looking more and more to extruded aluminum shapes for structural, architectural and industrial applications.

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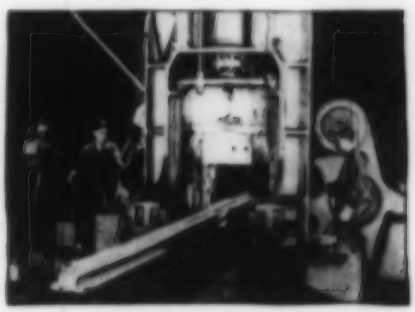
For more information on the profitability of using Bridgeport extrusions or for technical assistance in solving your design problems, get in touch with Bridgeport. You'll find a sales office near you.

Every production step is subject to strict quality control at Bridgeport Aluminum. This spectroscope detects alloy elements as low as 0.001 per cent.



This extrusion press—one of 16 at Bridgeport Aluminum—has a capacity of 5,500 tons. Any alloy now being extruded can be supplied.

Bridgeport

BRIDGEPORT BRASS COMPANY

ALUMINUM DIVISION

BRIDGEPORT 2, CONN.

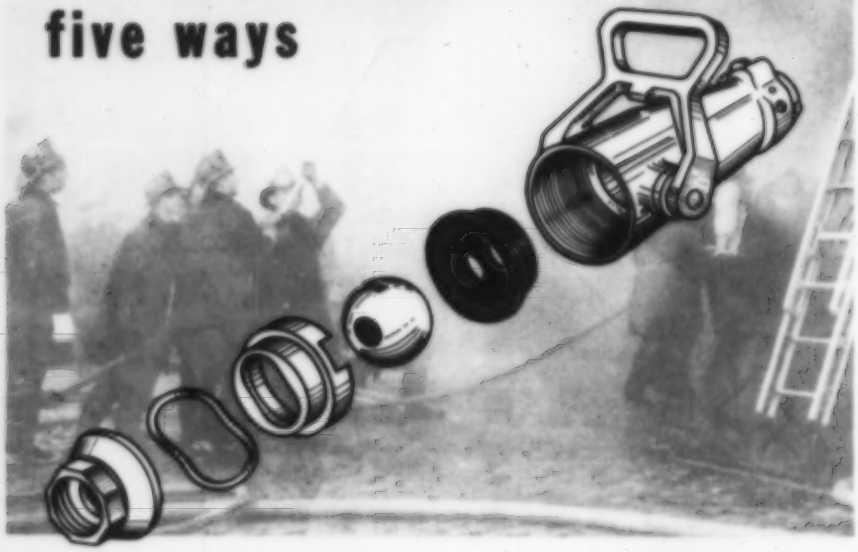
Sales offices in Principal Cities

Conveniently Located Warehouses

Mills at Bridgeport, Conn., Indianapolis, Ind., and Adrian, Mich.

BRIDGEPORT ALUMINUM

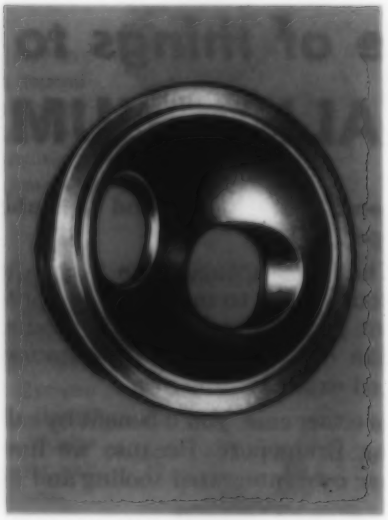
how IPC packings help Rockwood fight fire five ways



In Rockwood Sprinkler's all-purpose nozzle, fire-fighters have a basic weapon for fighting fire with five different types of water action. From high-velocity water fog to solid foam streams, the floating ball in the nozzle body can be positioned to the desired action.

A special dual-aperture packing, developed by IPC, seats and seals the ball *instantly*. Another unique problem . . . solved by IPC's thorough analysis of requirements, and their careful selection of packings material.

Pneumatic or hydraulic problems are best solved by IPC packings, either standard or special types, in leather or synthetic rubber. An IPC engineer will help you determine the best material . . . the most effective design. Write today!



This IPC packing, used in the Rockwood nozzle, is made of Buna N rubber (90 Durometer) and can withstand pressures up to 300 psi.

IPC

IPC PACKINGS

IPC *serves industry with cup, flange, U and Vee packings, oil seals and custom packings.*

Cup Flange U Vee Oil Seals

INTERNATIONAL PACKINGS CORPORATION

A subsidiary of Graton & Knight Company

Bristol, New Hampshire

P1

New Parts

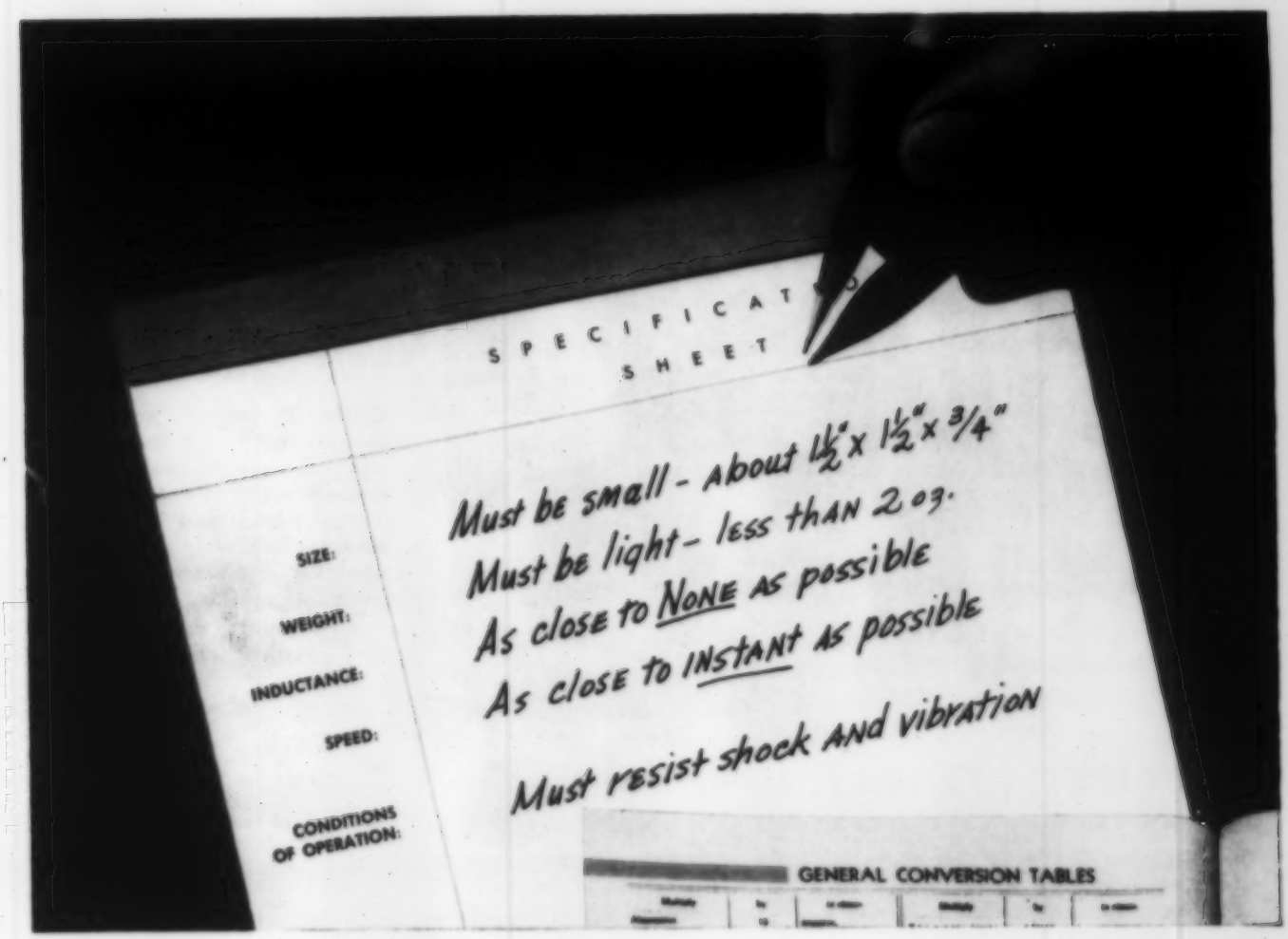
transmitted through precision-cut gears mounted in miniature precision ball bearings. Modifications include hysteresis-synchronous and capacitor induction motors at various voltages and frequencies. Made by **Eastern Air Devices Inc.**, 385 Central Ave., Dover, N. H.

For more data circle MD-121, Page 229

Magnetic Amplifiers

Ultra-Fast magnetic amplifier, first of a new line, was developed for use in control systems requiring a high-gain amplifier and fast response. Speed of response is independent of the number of stages of amplification, which makes possible this three-stage amplifier in which the input and output phases occur during the same half-cycle of the power supply. Reduction of the series major loop lag permits the use of more negative feedback in the inner loop, resulting in improved stability. These amplifiers can be used either as phase-reversible ac amplifiers or as polarity-reversible dc amplifiers for dc inputs with no changes in the internal wiring of the amplifier. Power gain is 50,000; power output is 15 w phase reversible with ac input or 15 w, polarity reversible with dc input. Total time lag is 0.0083-seconds. Load impedance is 800 ohms; input impedance, 15,000 ohms. Made by **Librascope Inc.**, 808 Western Ave., Glendale, Calif.

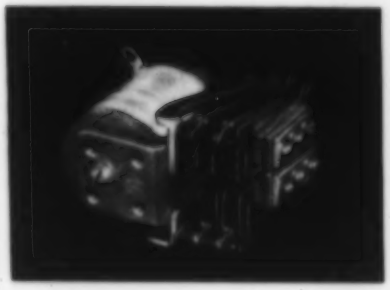
For more data circle MD-122, Page 229



When you list these requirements for a relay:

you've specified

the Automatic Electric Class S Relay!



Class S Relays are also available PLUG MOUNTED... to give these additional advantages:

minimized inventory

Manufacturers of process control equipment have standardized on plug-in relays. In that way a manufacturer can interchange the same basic relay in many of its models.

fast, simplified inspection and maintenance

Manufacturers of remote control assemblies specify "plug-in" relays; whole banks of relays can be removed in seconds.

adaptability to hard-to-get-at locations

Manufacturers of machine tools with space problems use "plug-in" relays. Less clearance space is required for installation or removal of relay.

For years the Class S Relay has been meeting conditions like these, and others just as exacting . . . distinguishing itself for dependability . . . amazing users again and again with its stamina.

It's used in aircraft to adjust propeller pitch and synchronize engines, to operate landing flaps and landing gear, to provide automatic pilot equipment with snap and accuracy. It's used in guided missiles. In radio and TV, it is employed to select channels, to repeat pulses. It has hundreds of applications in manufacturing process control, computers, telemetering, automation.

The Class S Relay *probably* has a space-saving, weight-saving, money-saving application somewhere in your products. We'll be glad to send you complete facts and figures on this and the many other Automatic Electric relays. Ask for Circulars 1702 and 1803.

Write: Automatic Electric Sales Corporation, 1033 West Van Buren Street, Chicago 7, Illinois. In Canada: Automatic Electric Sales (Canada) Ltd., Toronto. *Offices in principal cities.*

RELAYS **SWITCHES**

PRODUCTS OF THE INDUSTRIAL DEPARTMENT OF

AUTOMATIC ELECTRIC

CHICAGO

with
BIJUR
AUTOMATIC
LUBRICATION

Bijur Automatic Lubricating Systems designed into your machines *from the start* help you build an early lead in customer satisfaction.

And with Bijur you are *right* because for a quarter of a century Bijur Automatic Lubricating Systems have been part of efficient production programs.

Your customers prefer automatic lubrication in the equipment they buy because it increases production and reduces operating costs. Built into your original plans for machinery production, a Bijur Automatic Lubricating System can work for you by increasing customer acceptance, assuring bearing safety, and contributing to operating efficiency.

Call in a Bijur lubrication engineer. He is ready to help with your technical problems.

9-9

1934

BIJUR
LUBRICATING CORPORATION
Rochelle Park, New Jersey

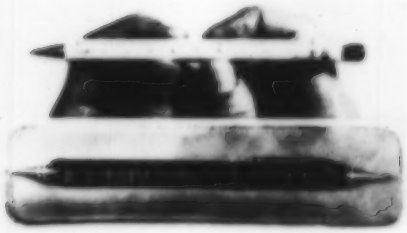
Pioneers in Automatic Lubrication

ENGINEERING DEPARTMENT

EQUIPMENT

Slide Rule Pencil

Operated like a conventional slide rule but made in the form of a mechanical pencil, Deveo series 400 slide rule pencil measures, calculates and writes; has a cursor, detachable straightedge, eraser, lead chamber and pocket clip. Design provides true slide-bar construction, permitting visual clarity, facility of manipulation,



high accuracy and versatility. Calculator is of white or black plastic and has heavily plated metal components. It is 6 in. long and weighs less than 1 oz. Six-scale, single-writing color and eight-scale, two-color models are available. Made by **Device Development Co.**, 226 W. Fourth St., New York 14, N. Y.

For more data circle MD-123, Page 239

Tracing Paper and Cloth

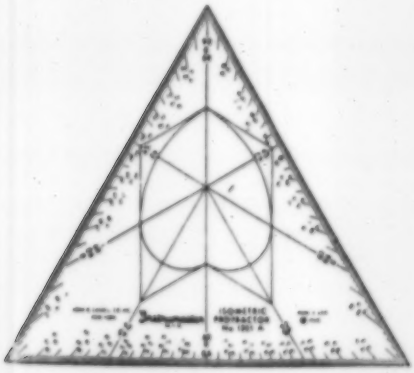
Included among six improved tracing papers and cloths is Whitney No. 378, a dual-purpose tracing cloth which accepts both ink and pencil equally well. Ink lines do not chip or flake off, and pencils as hard as 9-H neither skip nor damage the surface. Available in blue and white, it is water-repellent and impervious to common solvents. Tracing papers will not become brittle or lose proper transparency. Negligible leaching occurs after long storage

or where drafting tape is applied. The fine-grained surface is processed for accepting pencil lines with strong opacity. Made by **Charles Bruning Co.**, 4700 Montrose Ave., Chicago 41, Ill.

For more data circle MD-124, Page 220

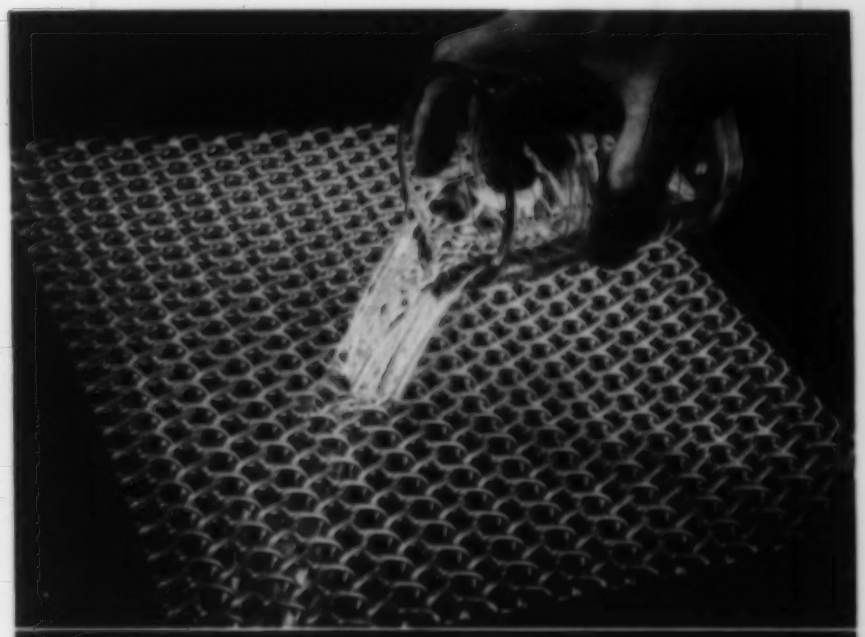
Isometric Protractor

This Instrumaster No. 1201-A protractor for isometric drawing contains two sets of 180-deg graduations, each numbered from 0 to 90 deg clockwise and counterclockwise from the main axes. Either half can be used for any one of three isometric planes. A geometrical figure around the



center of the protractor facilitates orientation of the instrument within the particular plane. Protractor has an outline of triangular shape in such relation to the graduations that correct orientation is obtained automatically by placing one of the instrument's edges against a T-square, straightedge or drafting machine blade. Two sets of numerals permit direct reading re-

(*Continued on Page* 300)



OPEN MESH!

Cambridge

WOVEN WIRE CONVEYOR BELTS

provide continuous, low-cost processing and handling

Open mesh construction of woven wire belts lets process atmospheres circulate freely for uniform cooling, heating, drying . . . provides flash drainage of solutions, rapid washing, quenching, cleaning, draining.

Whether you're designing machines for your own operation or for resale, you can eliminate batch handling, cut costs, provide continuous production at controlled rates of speed with moving woven wire belts.

All-metal Cambridge Woven Wire Conveyor Belts are corrosion resistant and impervious to damage from constant operation at temperatures from sub-zero to 2100° F. They have no seams, lacers or fasteners to wear more rapidly than the body of the belt . . . no localized weakening.

No matter how you look at it, CAMBRIDGE Woven Wire Conveyor Belts are invaluable aids to AUTOMATION . . . help beat your biggest competition, COST. They are made in any size, mesh or weave, from any metal or alloy. Special raised edges, cross-mounted flights and other surface attachments are available to hold your product during movement.

ANNEALING BRASS PARTS...Process atmosphere circulates freely through open mesh of Cambridge belt and around small or large parts.

Call in your Cambridge Field Engineer to discuss how you can cut ultimate costs by continuous operation. You can rely on his advice. Write direct or look under "BELTING, Mechanical" in your classified telephone book.

ASK FOR FREE 130-PAGE REFERENCE MANUAL illustrating and describing woven wire conveyor belts. Gives mesh specifications, design information and metallurgical data.

The Cambridge Wire Cloth Co.

WIRE CLOTH | METAL CONVEYOR BELTS | SPECIAL METAL FABRICATIONS

Department N
Cambridge 2, Maryland

OFFICES IN LEADING INDUSTRIAL AREAS

new

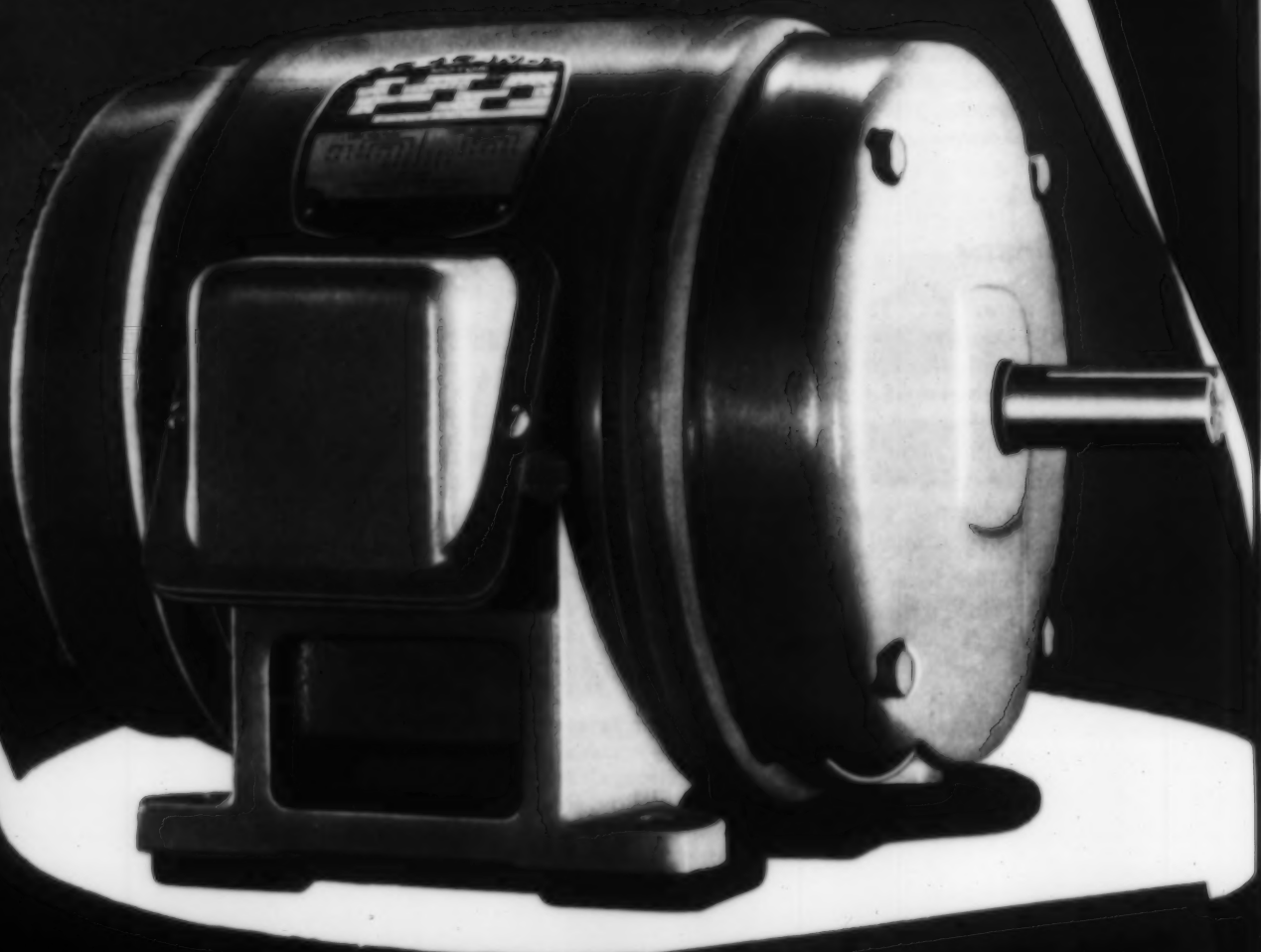
. . . and more efficient, too!

...tion!

...Custom-designed for regular ...

...built for a lifetime of service!

LELAND LOADSTAR MOTOR



Here are LELAND'S outstanding qualifications for ...

★ Extensive and continuing experience in developing and producing, for our Armed Forces, hundreds of thousands of portable generator units and airborne inverter units and controls. Leland designs consistently meet and frequently surpass specifications so satisfactorily that they virtually become the criteria for other suppliers.

★ More than 33 years' "creative electrical engineering" experience in supplying manufacturers with high-quality custom-built special motors, or standard ...

★ The combined, ... and development resources of American Machine & Foundry Company.

★ A unique combination of modern, mass-production facilities and custom craftsmanship, resulting in extra care in critical operations and greater versatility in production.

Hitch your product to a "Loadstar"!

YOUR NEWEST PRODUCT will have added value, added efficiency, when powered by the equally modern, equally efficient LELAND *"Loadstar"*! It's the most advanced LELAND motor ever designed for regular production!

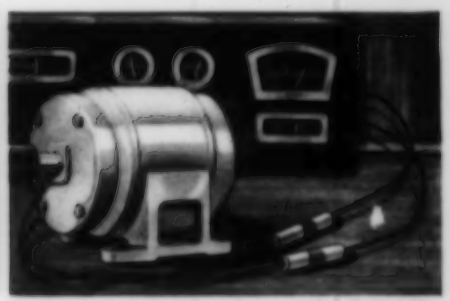
LELAND engineers have taken full advantage of the rare opportunity presented by the reframing program to incorporate into new LELAND designs many *added* improvements not actually a part of simple reframing. In this way every user of a new *"Loadstar"* motor benefits directly from LELAND's exceptionally pertinent experience in the continuing development and manufacture of special and lightweight power units and inverters for Aviation and the Armed Forces . . . one of the roles in which LELAND's creative electrical engineering has particularly distinguished itself.

No wonder, then, that the *"Loadstar"* outshines them all!

Some features of this new line of smaller, lighter integral horsepower motors are shown below. Others were covered in a previous advertisement. For the complete story, and frame dimension details, write for Bulletin No. 103.

Generous-sized, double-shielded, sealed ball bearings, *lubricated for life*, prevent entrance of abrasive grit. Precision-machined bearing bores give uniform rotor-to-stator air gap.

Simplified design: reduced number of parts; cast fans have same diameter as rotor, permitting rotor removal from either end; standardized components fit open or enclosed frames.



Performance tests prove, despite reduced size, the new motors attain higher efficiency, higher full-load speeds, approximately 30% higher starting torque and breakdown torque.

Stator construction features heavy Formvar windings and carefully annealed lamination punchings.

Non-rusting, easily read aluminum name plate plainly shows all wiring connections.

Large conduit box turns to four positions. Smudge-proof numbered markers identify leads.

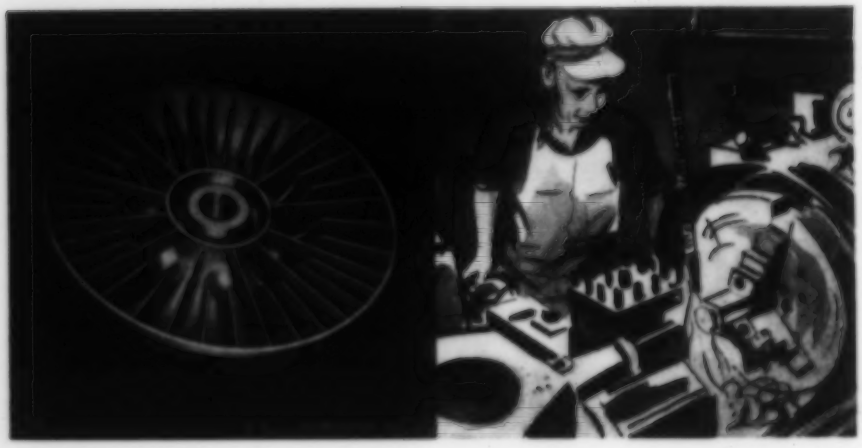
New "Loadstar" polyphase, dripproof motors in 1, 1½ and 2 HP (180 frames) now ready. Totally enclosed and explosion-proof frames — also higher horsepower and single phase motors — available soon.

Another AMF Product

LELAND MOTORS

LELAND motors in previous NEMA standard frames will continue to be available for replacement and the convenience of present customers.

THE LELAND ELECTRIC COMPANY, DAYTON 1, OHIO, *Division of American Machine & Foundry Company*



Factories and Fighters

Thompson Precision-Engineers Light Metal Castings for All Industry

THE machinist turning out production parts and the pilot flying the speedy jet fighter have one thing in common—both can count on Thompson. The factory worker's machine and the pilot's jet engine are each improved by precision-engineered castings produced by Thompson's versatile Light Metals Division.

In the case of the fighter, it's any one of several parts including the alternator housing that's produced by Thompson—with the factory machine, one of the parts manufactured by Thompson is the casting for the fluid clutch.

These are but two of the many light, strong, durable castings designed, developed and manufactured by Thompson for a diversified list of customer uses. Today Thompson is producing light metal castings for such products as buses and garbage disposers; washing machines and jet planes; automobiles and industrial engines; ice scoops and aircraft engines.

Behind this ability to aid all forms of industry are over 50 years experience in research and manufacture of precision metal parts. Regardless of your product, if you use castings, Thompson's creative engineers will gladly show you where and how you can simplify your operations and save on costs with Thompson Light Metals Castings.

For a detailed description of the Thompson Light Metals facilities which are available to you, send for your free copy of "Creative Castings." Just write to Dept. M-6, Light Metals Division, Thompson Products, Inc., 2269 Ashland Road, Cleveland 3, Ohio.

You can count on

Thompson Products

LIGHT METALS DIVISION
2269 Ashland Rd. • Cleveland 3, Ohio

Engineering Equipment

(*Continued from Page 297*)

gardless of which side of the protractor is placed on the drawing. Any angle in any plane of an isometric drawing can be plotted or measured directly so that lines not parallel with one of the axes can be drawn without "boxing" or using co-ordinates. Made by **John R. Cassell Co. Inc.**, 110 W. 42nd St., New York 36, N. Y.

For more data circle MD-135, Page 229

Lead Holder

The Constructor, a flat propelling lead holder, is designed for precise work. Lead inserts, which are 0.016-in. thick and 0.047-in. wide, never require sharpening and

can be used to the last fraction of an inch. A firm guide edge for straightedges and triangles assures accurate work. Device can be used for block printing as well as regular writing. Hard rubber knurled shaft facilitates handling of the lead holder. Flat ribbon lead inserts are available in four degrees of hardness—HB, H, 2H and 4H. Made by **Alvin & Co.**, Palisado Ave., Windsor, Conn.

For more data circle MD-136, Page 229

Oscilloscope Camera

Model OC-1 high-speed 35-mm camera for continuous recording of oscilloscope traces may be mounted directly on the bezel of any 5-in. oscilloscope. Installation illustrated includes simultaneous binocular viewing and recording, illuminated identification card and flashing lamp time reference. Camera's film capacity is 100 ft. Film transport rate may be set between 1 and 300 ips by means of a continuously variable remote motor control. Lower speeds can be achieved by gear substitution, and higher

Unitool*. . . *a fast, easy, low-cost way* to produce prototype bevel gears!

Now you can produce small quantities of spiral bevel, Zerol® bevel and hypoid gears with a comparatively small capital outlay and without specially trained personnel.

You can reduce the time and expense it takes to change your angular drive from a drawing board idea to a working model, too, because the Unitool Method produces good quality gears directly from the initial calculations.

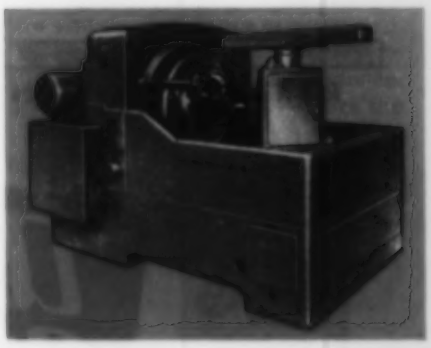
The Unitool Method is based on a fundamentally different theoretical approach to bevel gear generation. Only six different cutters are required to cut gears up to 18" pitch diameter—spiral bevel and Zerol bevel pairs of any ratio; hypoid pairs 3:1 ratio and higher. Because these cutters have a wide overlap in range, cutter diameter is not critical.

Calculations are short enough and easy enough for you to do in your own plant. Correct tooth thickness and position of contact are easily determined without requiring special operator training.

The Unitool Method is designed especially for the Gleason No. 106 and No. 116 Hypoid Generators which feature increased universal cutter tilt.

*Trademark

We will be glad to send further information on the Unitool Method and the two Gleason Generators best suited for it at your request.

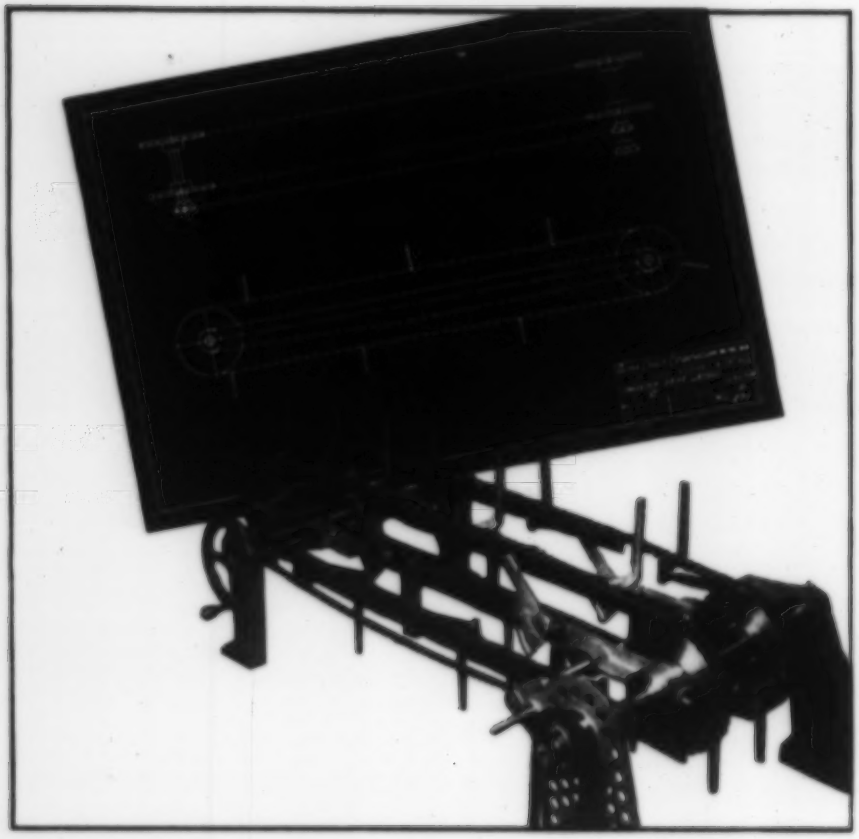


The Gleason No. 106 Hypoid Generator is a high-speed machine for spiral bevel, Zerol bevel and hypoid gears up to 8½" pitch diameter. Its larger counterpart, the No. 116 Hypoid Generator, handles the same type gears up to 18" pitch diameter.

GLEASON WORKS

Builders of bevel gear machinery for over 90 years

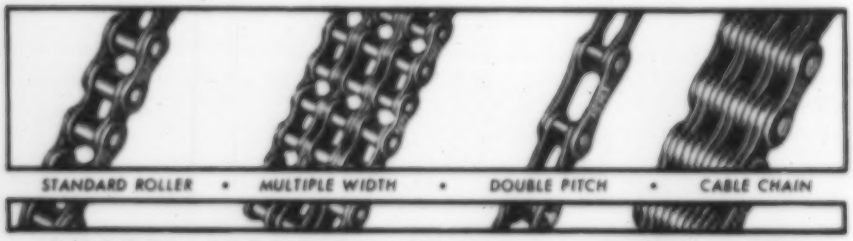
1000 UNIVERSITY AVE., ROCHESTER 3, N. Y.



Solution!

by ACME CHAIN ENGINEERS

ACME engineers are roller chain experts . . . continually abreast with the advances in roller chain application. Whatever your problem, involving chain, call for the voluntary service of an ACME engineer. *Write or phone JEfferson 2-9458.*



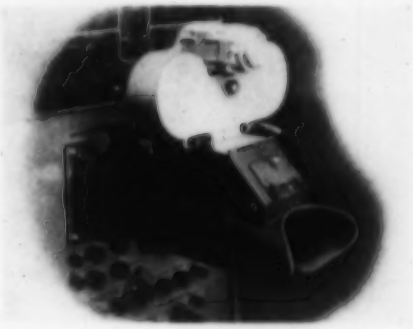
RUGGED PRECISION CHAIN for EVERY NEED

Write Dept. 6R for new illustrated 76 page catalog on use and application of roller chains and sprockets.

Acme Chain Corporation
HOLYOKE
MASSACHUSETTS

Engineering Equipment

speeds up to 400 ips can be reached with special starting acceleration control. Film consumed in starting or stopping at maximum speed



is less than 2 ft. Choice of F/1.5 or F/2.8, 50-mm coated lens with iris diaphragm is offered, giving an image reduction ratio of 4.5 in the usual 5-in. oscilloscope installation. Made by **Brea Instructments,** P. O. Box 248, Brea, Calif.

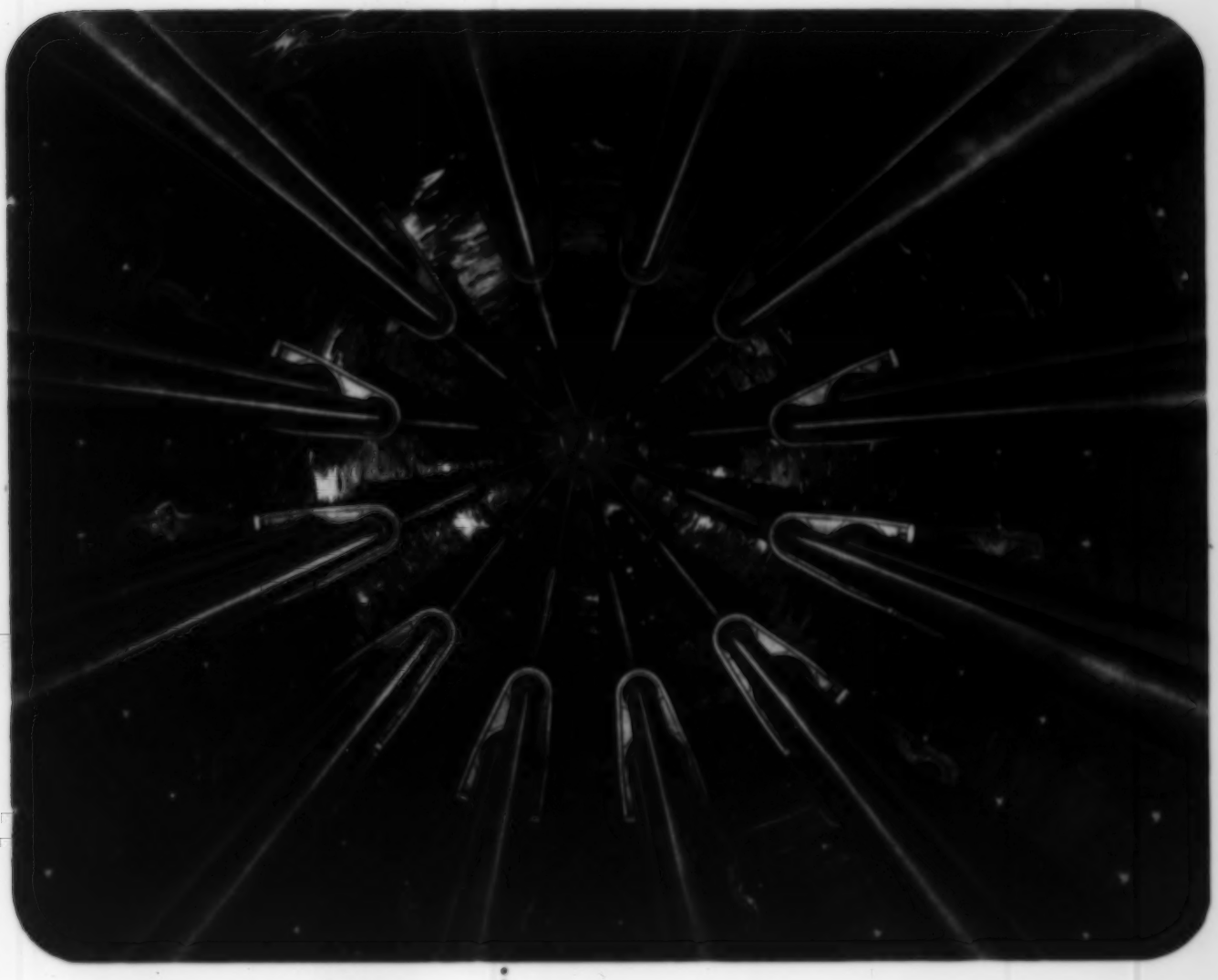
For more data circle MD-127, Page 229

Blueprint Reading Stand

Drawings up to 24 x 40½ in. are held in easy-to-read position by this metal blueprint reading stand. It has 6-ft support, or it can be wall-hung by means of a detachable easel. Usable anywhere, easel swings 360 deg and

tilts 25 deg. Prints are secured in place by six magnetized blocks. Easel and support can be lifted from base for portability. Assembly can be taken down for compact storage on a hook. Made by **Young Radiator Co.,** 709 S. Marquette St., Racine, Wis.

For more data circle MD-128, Page 229



TRENTWELD STAINLESS TUBING gives longer operating life...

TRENTWELD stainless steel tubing gives economical, trouble-free service over long periods of use. It's an ideal choice, for example, for applications such as the 60-foot rotary kiln dryer you are looking into in the photograph above . . . operating at high temperatures and where corrosive conditions are encountered.

In fact, you just can't buy better tubing than TRENTWELD for any application. That's because TRENTWELD stainless and high-alloy *welded* tubing is a product of tube mill specialists. Each tube has a uniformly sound weld indistinguishable from the parent metal and just as strong and corrosion-resistant.

Whether or not your job is as large and complex as a rotary dryer, you can specify TRENTWELD tubing with confidence. And when it comes to tubing sizes and finishes, Trent offers the widest range in the industry . . . from ⅛" to 40" O.D. and up. Next time you have a job involving tubing, remember—you can make it better with TRENTWELD.

FREE — Write for your copy of the new TRENTWELD price calculator. Just a tug at the selector slide gives you complete price information and weight per foot of the tubing size and grade you need. Better send for your free copy now.

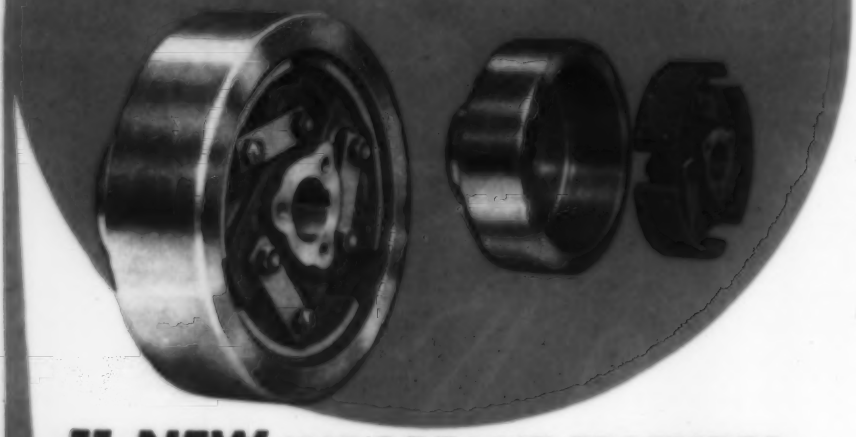
TRENTWELD

STAINLESS STEEL TUBING

TRENT TUBE COMPANY, GENERAL SALES OFFICES, EAST TROY, WISCONSIN (Subsidiary of CRUCIBLE STEEL COMPANY OF AMERICA)

Flexible ACTION IN THE New HILLIARD TWIFLEX

AUTOMATIC CENTRIFUGAL CLUTCH COUPLING



11 NEW IMPORTANT FEATURES..

1. Flexible in all directions.
2. Absorbs Shock.
3. Limits torsional vibration.
4. Has adjustable idle speed.
5. Can be furnished in automatic free-wheeling type.
6. Smooth starting.
7. No slip under normal load at full speed.
8. Protects driver and driven mechanisms against overload shock.
9. Can be furnished in automatic backstop type.
10. Prevents torsional resonance.
11. Easily assembled even in blind installations.

If you have problems of misalignment — smooth starting — vibration — overload — or assembly in the manufacture or operation of:

- Compressors
- Blowers
- Diesel Engines
- Excavators
- Refrigeration
- Hammer Mills
- Textile Machinery
- Wire Machines
- Fans
- Gasoline Engines
- Back Stop Brakes
- Mixers
- Conveyors
- Pumps
- Electric Motors
- Generators
- High Speed Pulverizers
- Tube Mills

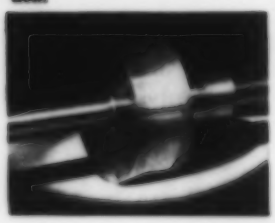
• Let Our Engineers Consider Your Problem. Twiflex May Be The Answer.

SINGLE REVOLUTION CLUTCH

For automatic, accurate control, electrically or mechanically, of intermittent motion, indexing, cycling, cut-off.

OVER-RUNNING CLUTCH

For automatic engagement and release on two speed drives, dual drives and for ratchet feed or backstop action.



SLIP CLUTCH

For overload protection — constant torque — constant tension on reeling or winding stands.

WRITE TODAY! For Details of TWIFLEX Coupling in Catalog CE-3

THE HILLIARD Corporation

103 W. FOURTH ST. ELMIRA, N.Y.

MANUFACTURING CLUTCHES FOR 50 YEARS

THE ENGINEER'S Library

Recent Books

Gears. *By H. E. Merritt; 541 pages, 5½ by 8½ inches, clothbound; published by Pitman Publishing Corp., New York; available from* MACHINE DESIGN, *$12.50 postpaid.*

This thorough treatment of the design, manufacture and use of gears is in its third edition. In 29 chapters it covers classification of gears; conventions; nomenclature, notation and definitions; pitch surfaces and tooth spirals; principles and analysis of tooth contact; principles of gear-tooth generation; geometry of involute spur, helical, spiral involute, conical involute, bevel and worm gears and gear generating cutters; detail dimensions of spur, helical, spiral, bevel and worm gears; special gear-tooth applications; gear-tooth accuracy and tolerances; tooth reactions and bearing loads; behavior of gears in service; gear materials; efficiency, lubrication and cooling of gears; loading and strength of gear teeth and their resistance to surface loading; working stresses and design factors; and gear trains. Appendixes include useful charts, tables and references.

•

Fundamentals of the Working of Metals. *By G. Sachs, research professor, director of metallurgical research laboratories, Institute of Industrial Research, Syracuse University; 166 pages, 5½ by 8½ inches, clothbound; published by Interscience Publishers Inc., New York; available from* MACHINE DESIGN, *$4.75 postpaid.*

This book presents an elementary description of basic phenomena which determine performance of metals during mechanical working. These phenomena apply equally to processing into simple shapes, and fabricating of these shapes into more com-

plex, finished parts. Six chapters cover effects of temperature and speed on forming; relations between chemical composition, phase changes and forming characteristics; effects of grain structure on forming; some general concepts of metal forming; basic types of forming methods; and progressive fabricating.

•

Materials of Construction. *By M. O. Withey, emeritus dean and G. W. Washa, professor of mechanics, College of Engineering, University of Wisconsin; 895 pages, 5¾ by 9 inches, clothbound; published by John Wiley & Sons Inc., New York; available from* MACHINE DESIGN, *$9.00 postpaid.*

Directed primarily to structural engineers, but containing information of use to designers, this book presents data concerning sources, manufacture and fabrication of principal materials of construction, including wood, concrete, and ferrous and nonferrous metals and alloys. It gives information covering their more important mechanical and physical properties, and the influence of various factors on these properties. Causes of defects and variations, and how they may be discovered, are discussed.

•

Welding for Engineers. *By Harry Udin and John Wulff, department of metallurgy, Massachusetts Institute of Technology and Edward R. Funk, engineering consultant, Goodyear Aircraft Corp.; 440 pages, 5½ by 8½ inches, clothbound; published by John Wiley & Sons Inc., New York; available from* MACHINE DESIGN, *$7.50 postpaid.*

Emphasizing the principles of welding as a separate engineering field, this textbook presents information on a wide variety of welding problems.

After an introductory chapter on welding processes, the remaining 15 chapters discuss cold, hot-pressure, and resistance welding; metallurgical reactions in resistance

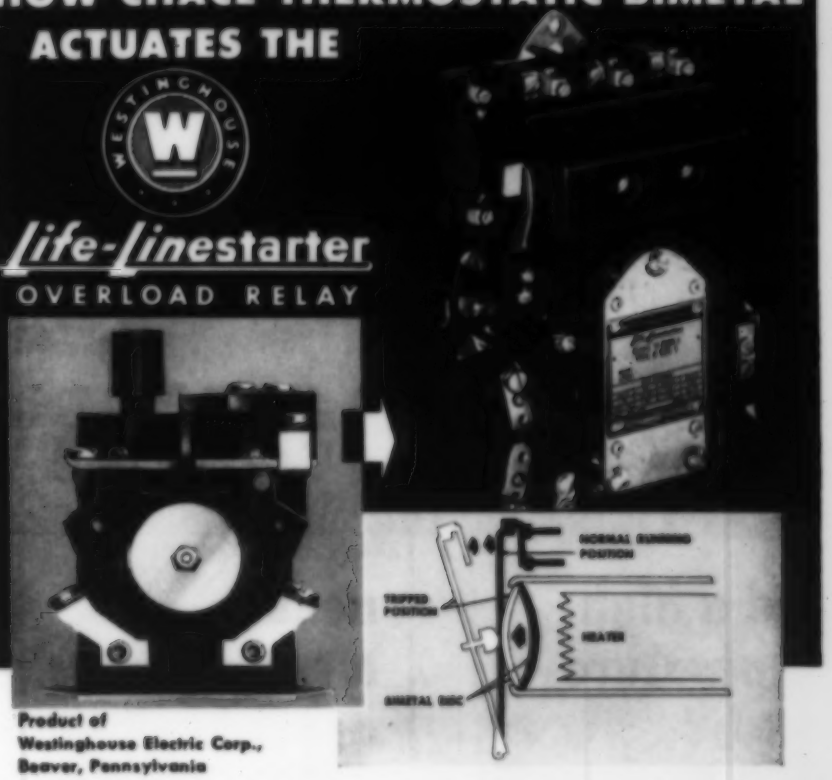
(*Continued on Page* 310)

HOW CHACE THERMOSTATIC BIMETAL ACTUATES THE

WESTINGHOUSE

Life-Linestarter

OVERLOAD RELAY



Product of
Westinghouse Electric Corp.,
Beaver, Pennsylvania

The Westinghouse Life-Linestarter provides positive protection against dangerous overload and motor burnout. This overload protection is accomplished by means of Chace Thermostatic Bimetal in the form of a snap-action, disc type of overload relay. This is a precision device, more reliable than conventional solder pot type relays since the bimetal disc retains its precise calibration over years of operation and is not affected by oxidation.

HOW IT WORKS

The overload relay is furnished set for hand reset operation. The relay may be set for automatic reset, hand reset or hand reset with no manual means of opening the contacts.

Under overload, the temperature of the heater element adjacent to the Chace Thermostatic Bimetal disc increases. When the temperature rise attains a predetermined level, it causes the bimetal disc to deflect from a normally concave to a convex position. The impact of the disc against the moving contact arm forces the contacts to open and break the coil circuit, opening the starter contacts and stopping the motor. When the bimetal disc cools, it snaps back to its normally concave position. After the cause of the overload has been eliminated, the relay is easily reset and the motor again started. The bimetal disc cannot be damaged by attempted reset at any time during its cooling period.

Chace Thermostatic Bimetal is available in 29 different alloy combinations, in strip, coil or in complete elements, fabricated to customer specification. Send for our new, free booklet, "Successful Applications of Chace Thermostatic Bimetal," containing valuable engineering information for designers of thermally responsive devices.

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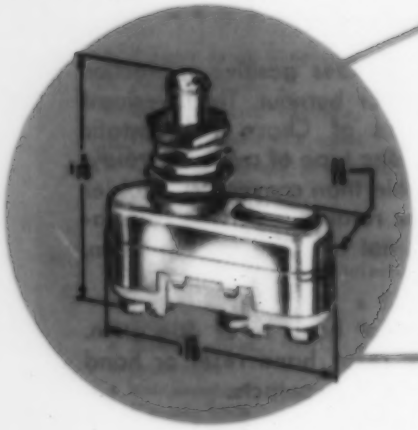
Thermostatic Bimetal
1616 BEARD AVE., DETROIT 9, MICH.

MICRO SWITCH Precision Switches
A PRINCIPLE OF GOOD DESIGN

There's that can meet requirement!

need a high temperature switch?

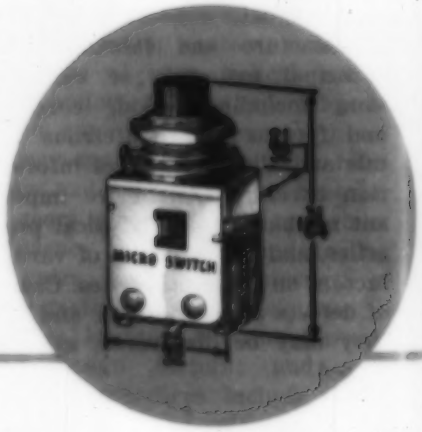


Does your design call for a switch that will operate perfectly at 1000°F? Originally designed to withstand the terrific heat of jet engines, this switch has met some very exacting requirements for a precision switch to operate in high temperatures. It has been found useful in equipment designed for distilleries, foundries, vulcanizing plants or other industries requiring high temperature components. For complete information and consultation on MICRO SWITCH precision switches contact your nearest branch office.

need a toggle switch assembly?

Many variations of these extremely small toggle switch assemblies are available for the control of multiple circuits. Shown is such an assembly for panel mounting which uses two SPDT subminiature switches to control up to 4 circuits. The small size of this switch permits mounting in minimum space behind panel. Other toggle switch assemblies are available which permit control of up to 16 circuits. If THE switch you need must do a big job in a small space check with MICRO SWITCH.

need a push button assembly?

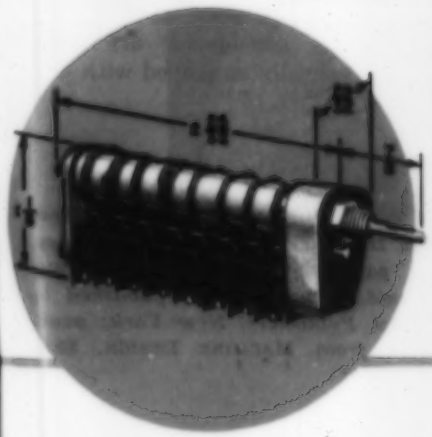


This is a subminiature push button switch assembly for two-circuit control. This switch provides an improved "feel" and simultaneous make and break of the two circuits. Other push button assemblies include one for panel mounting with the plunger mechanism sealed at the panel; also slide button assemblies where two subminiature switches are mounted in a three position, maintained contact assembly. Whatever your switch requirement it will pay you to contact MICRO SWITCH.

A complete line of precision snap-action and mercury switches

Only 1 Switch Your specific

need a subminiature rotary assembly?



Perhaps you need a small subminiature rotary selector switch. Here's one that will control from 2 to 16 circuits. It uses from 2 to 8 SPDT subminiature switches and permits from 2 to 8 switching positions with spring or manual return to neutral position.

Whatever the one switch you need to improve the performance of your design, there is—or can be—a MICRO SWITCH product to meet your requirement *exactly*. Call MICRO SWITCH today. It may save you time and money.

Let MICRO SWITCH Engineering Service help you select it!

- **Call your nearest MICRO SWITCH branch office today**

MICRO SWITCH provides a complete line of extremely reliable, small-size, high-capacity, snap-action precision switches and mercury switches. Available in a wide variety of sizes, shapes, weights, actuators and electrical characteristics. For all types of electrical controls.

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one service responsibility!

Instead of buying and aligning several separate units, install Reuland *tailor-made, single-unit Power Packages.* You save space and weight, reduce prices up to 25% — simplify installation—improve in-the-field performance.

Literally dozens of combinations are available to fit every powering job. All economical, *standard assemblies* using the basic Reuland "XPANDABLE" motor design.

If your equipment utilizes a motor, brake, fluid coupling, gear reducer (or any combination) why not find out first-hand what a Reuland Power Package can do for you. Give us the details and we'll even submit a "tailor-made" test unit on approval.

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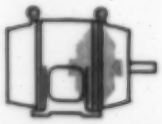
Still further versatility is provided by the Reuland "Library of Specials." Over 800 motors with special electrical and mechanical characteristics... 800 ways you can save development work, get in production faster!

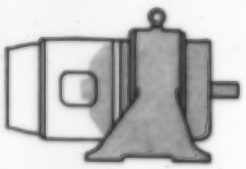
typical adaptations from this **BASIC DESIGN**

Motor with Reuland "Through Shaft" magnetic brake



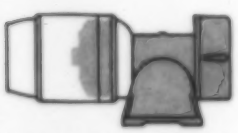
Motor with internal fluid coupling

Motor with fluid coupling and brake on output shaft



Motor with fluid coupling and helical gear reducer

Motor with fluid coupling, output shaft brake and helical gear reducer (second brake may also be added)



Motor with fluid coupling, right-angle worm reducer and brake

Write today, outlining your particular power problem. No obligation, of course.

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The Engineer's Library

(*Continued from Page 307*)

welding; heat and temperature during fusion welding; permanent-electrode and consumable-electrode arc-welding processes; welding with chemical heat sources; metallurgy of fusion welding; brazing; mechanical effects; and principles of weld inspection and testing. A glossary of welding terms is appended.

•

Adhesive Bonding of Metals. *By George Epstein, research engineer, North American Aviation Inc.; 228 pages, 4 by 6½ inches, clothbound; published by Reinhold Publishing Corp., New York; available from* MACHINE DESIGN, *$2.95 postpaid.*

Purpose of this book is to aid engineers in determining feasibility of adhesive-bonded joints, type of adhesive to select, how to employ the adhesive, and how to design joints for optimum performance. Adhesives considered are those most generally employed with metals.

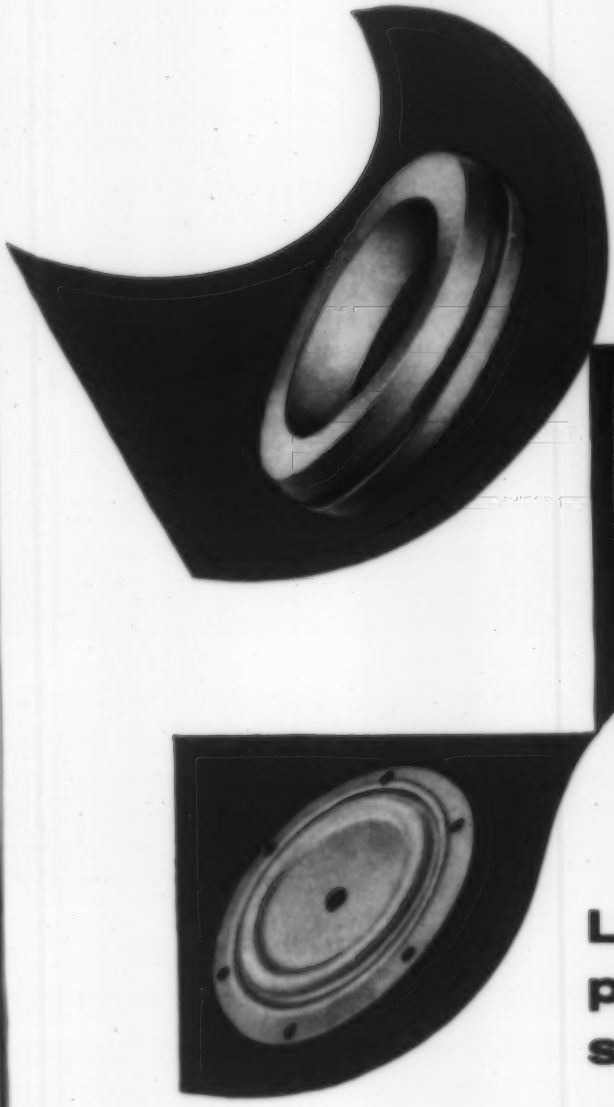
•

Patent Fundamentals for Engineers. *By H. K. Leonard, patent attorney; 39 pages, 5½ by 8½ inches, ring-bound, paper covered; published by Pelex Publishers, New York; available from* MACHINE DESIGN, *$2.00 postpaid.*

This booklet presents patent information of value to creative engineers who wish to protect their interests in inventions and designs. Subjects covered include qualifications for obtaining a patent, parts of a patent and their purpose, scope of patent claim, claim infringements, "utility," how patents affect engineers, rights of employed inventors in their inventions, and employment contracts.

New Standards

Drafting Standards — Aluminum Extruded and Tubular Products. *56 pages, 6 by 9 inches, paperbound; available from The Aluminum Association, 420 Lexington Ave., New*



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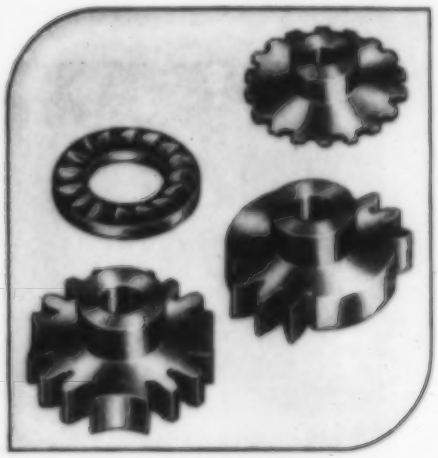

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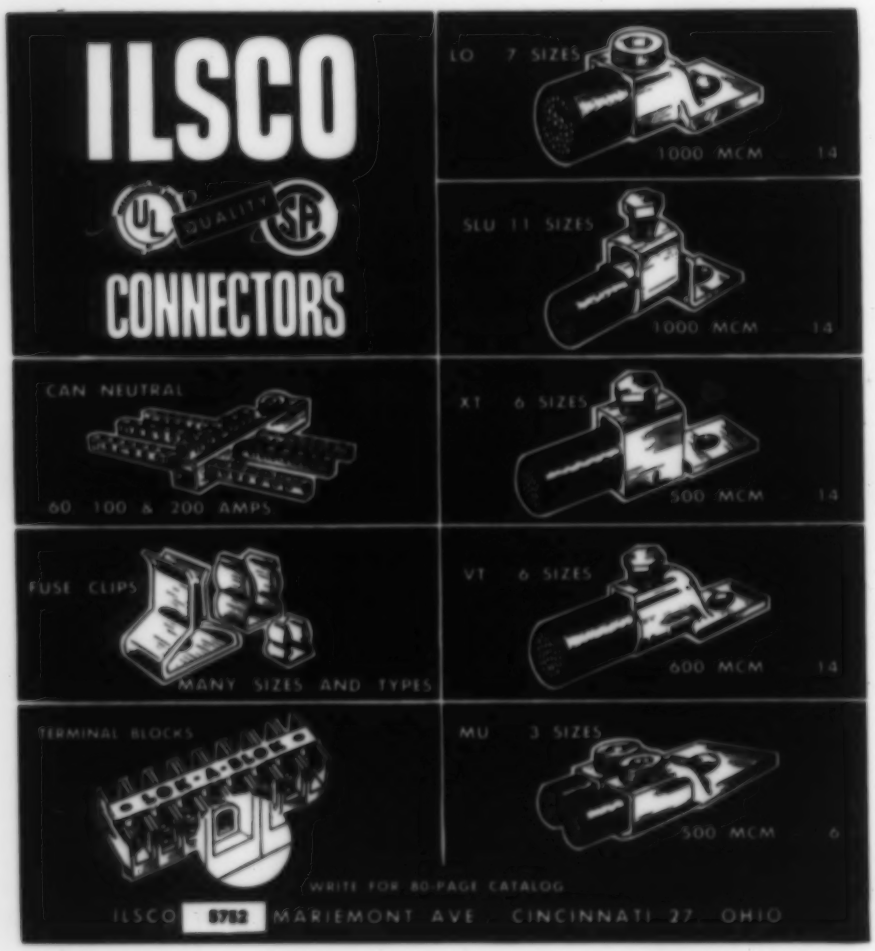

The Engineer's Library

York 17, N. Y., on company letterhead request.

The second edition of this manual outlines basic design practices necessary with extruded products and standardizes those practices as far as seems practical. Experience gained since publication of the first edition has warranted changes in tolerances in a number of cases.

•

Standards for Transformers. *Publication No. TR1-1954; 71 pages, 8½ by 11 inches, paperbound; available from National Electrical Manufacturers Association, 155 East 44th St., New York 17, N. Y., $3.00 per copy.*

These standards provide practical information concerning rating, performance, testing, manufacturing and marking of power and distribution transformers. This new book supersedes Publication No. 48-132.

Manufacturers' Publications

Bunker Hill Zinc and Die Casting. *24 pages, 8½ by 11 inches, paperbound; copies available from St. Joseph Lead Co., 250 Park Ave., New York 17, N. Y.*

This booklet contains technical data on zinc as a base metal for die casting alloys. It includes the variety of commercial finishes which may be applied to zinc base die casting and applications of such castings in industry.

Government Publications

NACA Technical Series. *Each publication is 8 by 10½ inches, paperbound, sidestapled; copies available from National Advisory Committee for Aeronautics, 1924 F St., N.W., Washington 25, D. C.*

The following Technical Notes are available:

3280. **Electrical Analogies for Stiffened Shells with Flexible Rings**—35 pages

3292. **Influence of Exposed Area on Stress-Corrosion Cracking of 24S Aluminum Alloy**—22 pages

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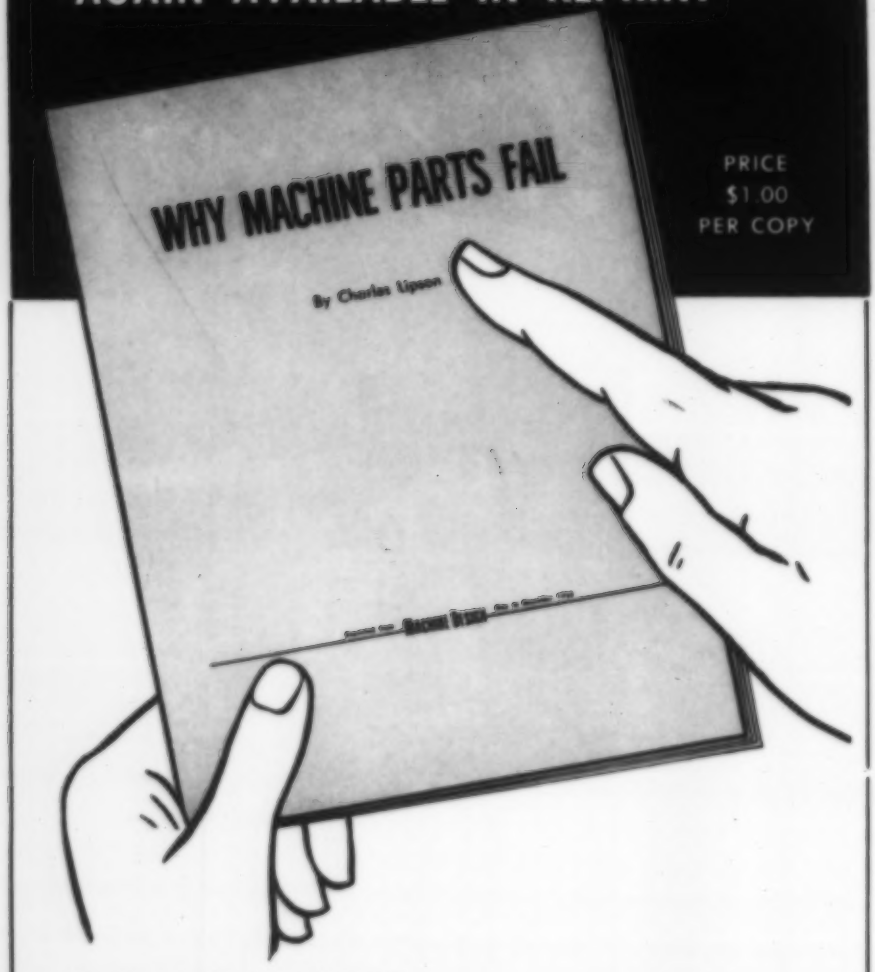

It's not new but it's still useful.

This is an obvious deduction from almost four years of continued requests for copies of "Why Machine Parts Fail".

Charles Lipson's tremendously popular series first appeared in the May 1950 issue of MACHINE DESIGN and was concluded in the December issue of the some year.

It was reprinted in 1951 to meet the demand for copies. But that supply ran out nearly a year ago.

Not so the requests. They have continued in such volume that we have decided to reprint the series again.

You can get copies by simply filling out the form below and sending it in to us. We shall appreciate your enclosing remittance to facilitate handling.

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Stress Relief

TECHNICAL society meetings and trade shows and expositions have come a long way in recent years in providing meeting grounds and market places. As a veteran at such affairs, J. P. Henderson here begins a personally conducted tour of

The Engineering Convention

This past summer I attended another engineering convention. Long ago I lost track of the number of these I've gone to. But as I sat in the hotel lobby viewing the familiar hubbub, it occurred to me that the engineering convention was quite an institution. Do you attend them? Do you get your full share of value for your employer's money? As a possible guide book for the uninitiated, let's trace the convention from beginning to end.

Register Early!

It really starts, of course, with the long line in the hotel lobby in front of the room registration desk, early in the morning. Delegates to the convention can be recognized by their already tired appearance. They didn't sleep well on the Pullman (unlike the hardened salesman). That's the first degree of tiredness one recognizes.

The second group sat up all night; they either failed to get reservations by last-minute changes in plans, or are traveling on their own money.

The third group are by far in the worst condition. For them the convention started the evening before in the club car. They had Pullman reservations but didn't go to bed, having too much gossip to exchange and too many strange chemical compounds to sample. They can be further recognized by the odor of these chemicals which still clings about them, and the enlarged veins in the eye.

There they are, all lined up in front of a man with a carnation, who is idly flipping a number of

FLEXLOC AT WORK

MORE AND MORE FLEXLOC LOCKNUTS are being used on applications where dependable locking is essential to the operation of the equipment and the safety of the operator. This bundling chain with automatic lock provides positive grip and safe, sure bundle handling.

Two FLEXLOC Self-Locking Nuts hold this assembly together. Once the locking threads are fully engaged, the nuts won't work loose, regardless of the conditions under which they are used.

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DO YOU KNOW? Standard FLEXLOCS smooth off rough bolt threads. The locking threads on all-metal FLEXLOCS are not chewed up when used on rough bolts.

Standard FLEXLOCS lock securely on bolts varying in diameter tolerances. The all-metal, resilient locking sections of the nut accommodate themselves to the diameter tolerances.

Standard FLEXLOCS are one piece, all metal. They are not affected by temperatures to 550°F. Nuts lacking these features have a more restricted temperature range.

Standard FLEXLOCS lock securely—stopped or seated—when 1½ threads of a standard bolt are past the top of the nut.

Standard FLEXLOCS are not affected by moisture, oil, dirt or grit. They lock efficiently under all conditions, regardless of the vibration encountered.

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LOCKNUT DIVISION
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today's most versatile recording system

Combine* Consolidated's Type 5-119 Recording Oscillograph with the Consolidated Amplifier System D, and you have an analog data-recording system usable on over 90% of all static-dynamic tests. As a compatible *team* of instruments, the 5-119 and System D can go anywhere (it's an ideal flight-test system), can record over a suprising range. And both instruments offer operating features and conveniences that make the combination truly today's most advanced analog instrumentation system. And every instrument is backed by Consolidated's nation-wide engineering and service organization.

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THE 5-119 RECORDING OSCILLOGRAPH . . . 36 or 50 channels . . . 12"x250-ft records at speeds from 0.1 to 100 inches per second . . 10 : 1 *instant* speed change by simple switch control . . . unique warning and safety devices to insure against loss of vital test data. SEND FOR BULLETIN CEC1536A-X1

**Or use them separately . . . either the 5-119 or System D may be combined with other recording and amplifying instruments. Write to us or talk to a CEC Field Engineer about your requirements.*

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Stress Relief

cards in his hand. Every now and then this clerk retires behind a screen, returning with more cards. Occasionally he writes a number on the registration card of the long-suffering victim patiently standing in line.

The convention delegate, anxious to get to his room and get cleaned up, should not be in a hurry. He must cultivate this patience. It's a long-established custom. There are, perhaps, 300 empty rooms in the hotel. The clerk must know their numbers.

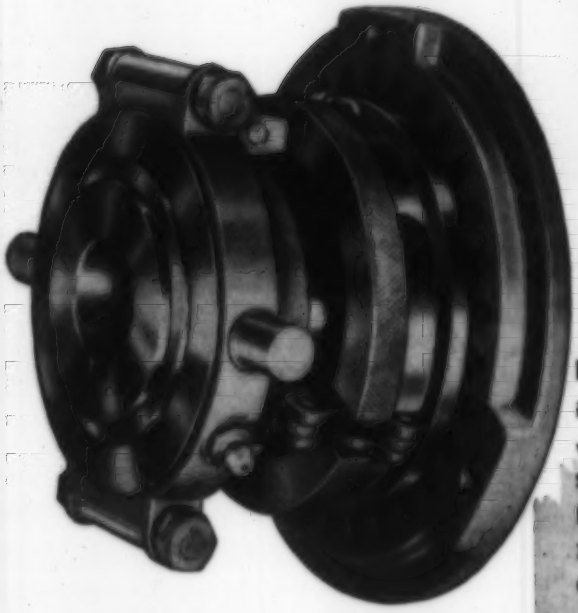
But they cannot be assigned without much walking back and forth, several conferences, and a series of severe examinations of many cards. When I was young and observed this procedure I thought, "Ah, here is a new clerk." Ten years later the same man, signing me in at the same hotel, had improved a great deal in his technique. As a result of his experience he had learned several additional places to look for these mysterious cards and had easily doubled his time.

If you are very lucky you will get your room once you have reached the head of the line. The alternative is to be told that no more are empty now.

"Check back at the desk about noon." Here is where experience comes in. The wise delegate recognizes an old friend away ahead of him in the line. In stepping up to greet him he mentions casually, "Looks like a long line this morning. I imagine most of us won't get rooms until this afternoon. If

(Advertisement)

Check JOHNSON single disc a Better CLUTCH for the same money



Better

BECAUSE . . .

it's the only clutch with SEPARATOR SPRINGS that prevent heating in both HORIZONTAL and VERTICAL installations.

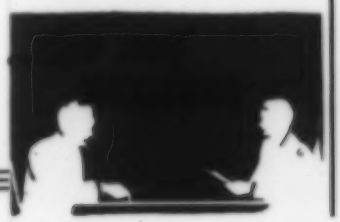
For some time there has been a demand for a single disc clutch for positive control of power transmission in the field of light machinery . . . a clutch that would stay cool on the job in both horizontal and vertical installations. This is "it."

If extreme compactness is not an essential, the Johnson No. 350 (3 h.p. max.) and No. 450 (6 h.p. max.) will meet or beat competition . . . as a better clutch at a competitive price. They incorporate most of the design principles of our Maxitorq multiple disc . . . and except for compactness and capacity, you will find them tops in their field. (Please read column at right . . . "Frankly Speaking" . . . for use recommendations.)

Several driving combinations are available, including V-belt. A simple hex key frees the knurled ring for easy manual adjustment. The "floating" disc prevents drag, abrasion, and heating in neutral. Machine and product designers will solve many problems in the light machinery field with this new Johnson single disc Clutch.

Send for Bulletin No. 250-MD-2

THE CARLYLE JOHNSON MACHINE CO.
MANCHESTER . . . . . CONNECTICUT



Frankly SPEAKING

Because of a large backlog of orders, The Carlyle Johnson Machine Company found it necessary to postpone the announcement of the new Johnson Single Disc Clutches.

Now, with added equipment for high speed production, it is possible to produce and ship the new clutches without undue delay. In fact, small orders or units for try-out in new machines will be forwarded at once. Design features make the Johnson especially suitable for installation in the following machinery:

Accessory Drives, Air Compressors, Bag Making, Boat Drives, Bread Wrapping, Chain Drives, Combines (farm), Conveyors, Crop Seeders, Cultivators, Dusting Machines, Feed Grinders, Floor Scrubbing, Fruit Cleaners, Gasoline Engines, Generator Drives, Hay Balers, Hoists, Loaders, Lawn Mowers, Milk Coolers, Mixing Machines, Motor Scooters, Packaging Machines, Paper Shredders, Power Fans, Power Saws, Power Take-offs, Pumping Equipment, Sand Spreaders, Sewing Machines, Sheep Shearers, Spraying Equipment, Textile Machinery, Threshers (small), Tobacco Machinery, Tool Grinders, Tractors (garden), V-Belt Drives, Vegetable Sorters.

Naturally, these are but a few of the possible applications for the Johnson Single Disc Clutch. The field is wide open, with new machinery constantly being developed.

Included in the driving combinations are: Gear Tooth, Bolted Plate, Pulley Type, Hub Adapter, Cut-off Coupling Adapter, Single V-Belt Pulley Drive, and Double V-Belt Pulley Drive.

Carlyle Johnson engineers offer their engineering assistance in cooperation with your engineers and machine designers to develop the correct solution of your power transmission requirements. Write to Frank R. Simon, The Carlyle Johnson Machine Co., Manchester, Conn.

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"in production"

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die cast **tiny parts**

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This is standard procedure—one need not be abashed at trying it; and it's as good as an ace up the sleeve. If you are really welcome, the friend, on clearing the desk, will stop by and tell you his assigned number.

Once you have removed the remains of the filtered, cooled air of the Pullman from your system, you have one more registration to go through. This is the engineering society line-up, usually handled with notable efficiency.

Register by mail, ahead of time, is my advice. Then step up to the desk, give your name and pay the registration fee. Before the echo of the bell has died away from the cash register, you have

had pressed upon you one large badge with your name and address, a printed program of technical papers, a social program, a list of tours of the city and a blurb from the local Chamber of Commerce.

The uninitiated, impressed by this speed, is inclined to move away to join the group of uncomfortable, ill-at-ease delegates who are wandering aimlessly through the lobby, or perhaps join some acquaintances talking quietly in the corner. On the other hand, he shouldn't overlook another ritual. He should get acquainted with the girls behind the convention registration desk, making sure that his badge is conspicuously placed so that they can get his name. Do not slight this suggestion I'll explain this point a little more next month.

—J. P. HENDERSON

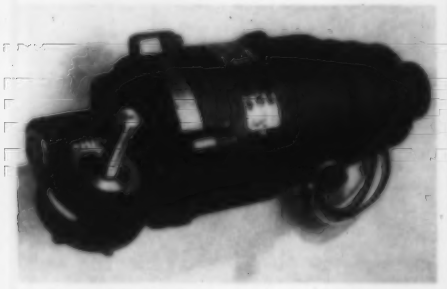
DOW CORNING CORPORATION

Silicone News

FOR DESIGN ENGINEERS

Silicone Grease Saves Money; Increases Life of Alloy-to-Plastic Gears in Precision Gearmotor

Using the best organic lubricants, maximum life of the gear set in a test model of a new precision gearmotor designed by Lee Engineering Company of Milwaukee, was only 100 hours. Temperature at point of contact between the nickel alloy worm and phenolic gears was so high that organic lubricants were rapidly separated and thrown out, even though the gearbox was fully packed.



Before major alterations in design were undertaken, Lee engineers tried Dow Corning 33 Grease, light consistency. A first trial run of 1200 hours showed no appreciable gear wear. Further tests proved that a basically sound design had been made practical by a stable lubricant.

With only enough Dow Corning 33 to fill the teeth required to give long service, Lee engineers found that even the initial cost of the silicone grease was less than that of a gear box-full of the organic grease previously tried.

Now in commercial production, these silicone lubricated precision gearmotors are put to many uses. For example, the ⅛ hp unit shown here with a 40 to 1 gear ratio and a speed range of 10 to 200 rpm on the phenolic gear, is used to feed wire in an automatic welding machine. *No. 24*

New 1955 Reference Guide to Dow Corning silicone products gives in 8 pages a brief but comprehensive summary of the properties and applications for the silicone products that are most widely used. Products are indexed by type of application. With increasing effort devoted to product improvement and cost reduction, such a reference guide to this remarkably stable group of engineering materials becomes increasingly important to design engineers. *No. 25*

RF Transformers Impregnated with Silicone Fluid Exceed Humidity Specs

The RF transformers in radio compasses made by LearCal Division of Lear, Incorporated, passed Ordnance tests for moisture resistance and extreme thermal shock. Lear felt, however, that for permanent protection, the transformers should be potted to come as close to forming a true hermetic seal as possible.

After potting with mica-filled epoxy resins, the transformers are, therefore, vacuum impregnated with Dow Corning 200 Fluid. Silicone treated transformers easily pass the humidity tests of SC-D-1594 and MIL-E-5400. They may be immersed in water for 30 minutes with no change in electrical properties. *No. 26*

Westinghouse Seals New Switches With Silastic for Sub-zero Service

Sealed, top and bottom, with Silastic gaskets, the new Westinghouse gas-filled, load interrupter switches remain operable at temperatures as low as —65 F. Organic rubber seals were originally tried, but sub-zero weather caused the seals to harden and shrink, allowing the sulfur hexafluoride gas to escape.

On testing, Westinghouse engineers found that Silastic gaskets easily passed all pressure, vacuum, and temperature requirements, and were not affected by the gas. The Silastic gaskets provide such a tight seal that Westinghouse expects the units to hold gas pressures of 30 psi indefinitely without recharging. *No. 27*

Silicone Aluminum Paint Protects Jet Engine Combustion Chambers

The materials used in many of the combustion chambers and burner supports manufactured for J-35 jet engines by Solar Aircraft of Des Moines, must remain unaffected by abnormally high temperatures. Aluminum clad steel solves the problem satisfactorily with exception of various fusion welds. These must be recoated with aluminum or a noncorrosive coating that will withstand up to 800 F.

Solar engineers have the answer to that problem, too. They simply spray or dip the welded part with two coats of Sicon, an aluminum paint formulated with Dow Corning silicone resins by Midland Industrial Finishes.

After a one hour bake at 400 F, the silicone based coating provides the required protection. According to Solar, this is one of the most satisfactory paints for use on jet engine parts. *No. 28*

Design Edition 6

DOW CORNING CORPORATION - Dept. 6802
Midland, Michigan

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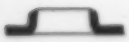

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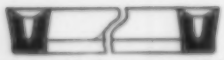

PALMETTO U-RING—New rugged design with wide lip flare for use in cylinders made from commercial tubing honed up to .030 over nominal sizes. Same sizes available in synthetic or fabric construction permits interchangeability of packing in low or high pressure cylinders. ALLOWS STANDARDIZATION OF COMPONENT PARTS ... INCREASES EFFICIENCY ... REDUCES FRICTION. ALSO RECOMMENDED AS ROD SEAL.

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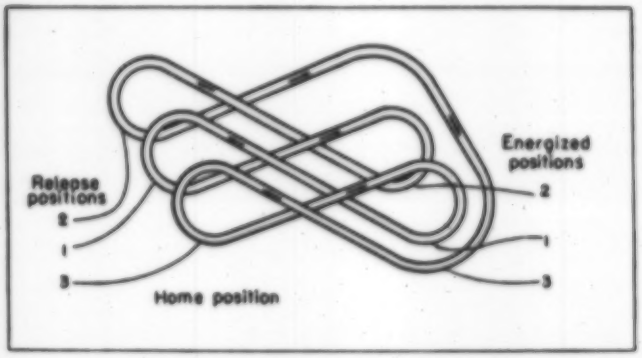
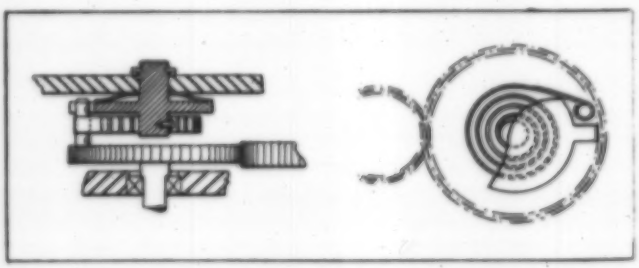
NOTEWORTHY Patents

STEPPING SWITCH for automatic-control applications consists of a series of figure-eights made of hollow tubing containing a globule of mercury as the contacting element. Tilting of the tubing back and forth by a solenoid causes the mercury to run around one figure eight for each oscillation. At the last



position, the switch may be tilted to cause the mercury to flow back to the starting position. Reverse flow of the mercury is prevented by mounting the assembly so the tubing behind the globule is always uphil. *Patent 2,677,031 assigned to Automatic Electric Laboratories by D. N. MacDonald.*

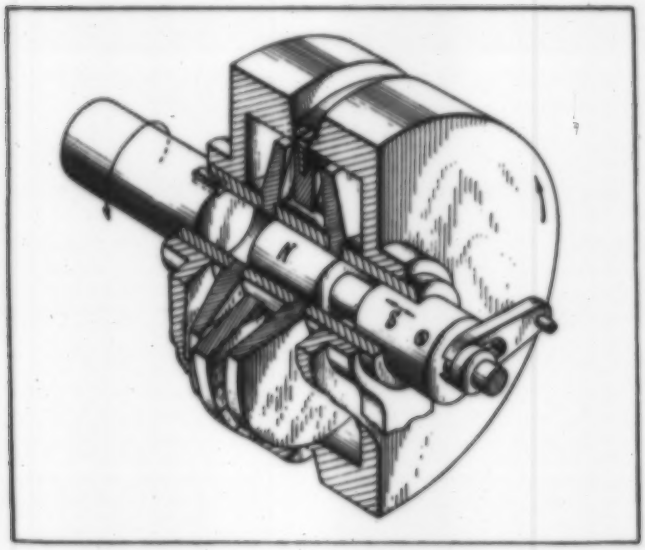
AUTOMATIC BACKLASH TAKEUP for instrument gears is provided by a coiled retraining spring in conjunction with a friction clutch assembly. Pressure of mating gear teeth is assured by the coiled spring: one end is fixed to the driven gear, other



is mounted on a friction disk. Upon rotation of the driven gear, the spring is wound up. Additional revolutions rotate the friction clutch assembly per-

mitting the entire spring to rotate with the gear. Thus, gear tooth pressure may be maintained over an unlimited number of rotations of the gear drive rather than limited by the length of the spring. *Patent 2,679,167 assigned to Kollsman Instrument Co. by D. B. Nichinson.*

MAGNETIC FLUID COUPLING for constant-torque drives is controlled by a permanent magnet. Two magnetizable disks mounted on a hollow drive shaft comprise the driving element. Power is taken off the outer case which is driven through magnetic fluid in the space between the two disks. Magnetic flux between the driving disks is controlled by a bar-shaped permanent magnet fitted to slide axially inside the hollow drive shaft. Minimum torque is transmitted when no magnetic flux passes passes between

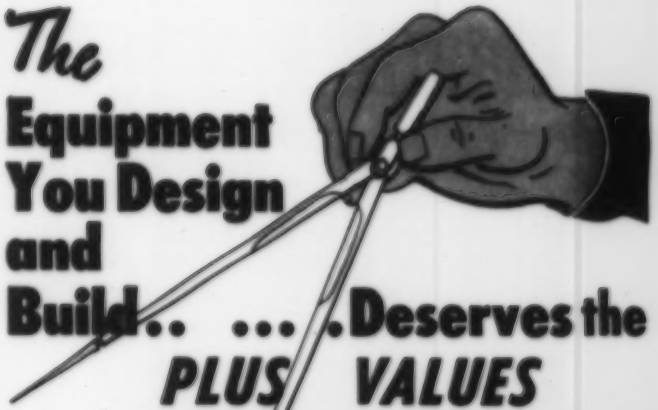


the disks to magnetize the fluid particles. This condition exists when either the north or south pole of the bar magnet is in a position to magnetize each disk in the same polarity. Maximum torque output occurs when the disks are magnetized in opposite polarities, which results in maximum flux between the disks and "freezes" the magnetic fluid particles. Torque transmitting characteristics of the clutch can be varied smoothly from maximum to minimum by moving the bar magnet back and forth. *Patent 2,671,545 assigned to Stewart-Warner Corp. by M. Petroff.*

QUICK DISCONNECT COUPLING for radio or instrument indicator shafts consists of a pin and disk arrangement. It can be locked in either the engaged

(*Continued on Page* 326)

The Equipment You Design and Build... ....Deserves the PLUS VALUES of WISCONSIN Heavy-Duty Air-Cooled ENGINE POWER



Wisconsin Heavy-Duty Air-Cooled Engines offer the design engineer, power equipment manufacturer and the ultimate user the cumulative benefits of many years of exclusive specialization in the heavy-duty air-cooled engine field.

The completeness of the line, comprising 12 models in 4-cycle single cylinder, 2- and 4-cylinder types and sizes ranging from 3 to 36 hp., provides close selectivity to fit your equipment and its service applications without power waste, yet retaining maximum power advantage. The benefits of "Wisconsin Standardization" on a variety of types and sizes of your own original equipment can be important to you. Some of the "Plus Values" of Wisconsin Power include:

Heavy-Duty engineered design and construction in all details; self-cleaning, file-hard tapered roller bearings at BOTH ends of the crankshaft; an easily accessible rotary type, high tension OUTSIDE Magneto, equipped with Impulse Coupling for quick starts in any weather, at low cranking speed; pump circulated splash lubrication on smaller models and geared oil pump delivering individual oil stream to each rod on multi-cylinder models, plus efficient AIR-COOLING at temperatures up to 140°.

All this adds up to efficient Power Performance, Long Engine Life and Low-Cost Maintenance . . . factors of vital importance in relation to the operation of your original equipment.

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Our Engineering Department will be glad to cooperate with you in adapting Wisconsin Engines to your equipment. Complete your data files with a copy of our 64-page "Blue Book", Form S-150, illustrating more than 250 Wisconsin Engine service applications, together with engine specifications.

Models ABN, AKN, AEN, 4-cy. single cyl., 3 to 8¼ hp.

Models AFH, AGH, AHH, single cylinder, 6 to 9 hp.

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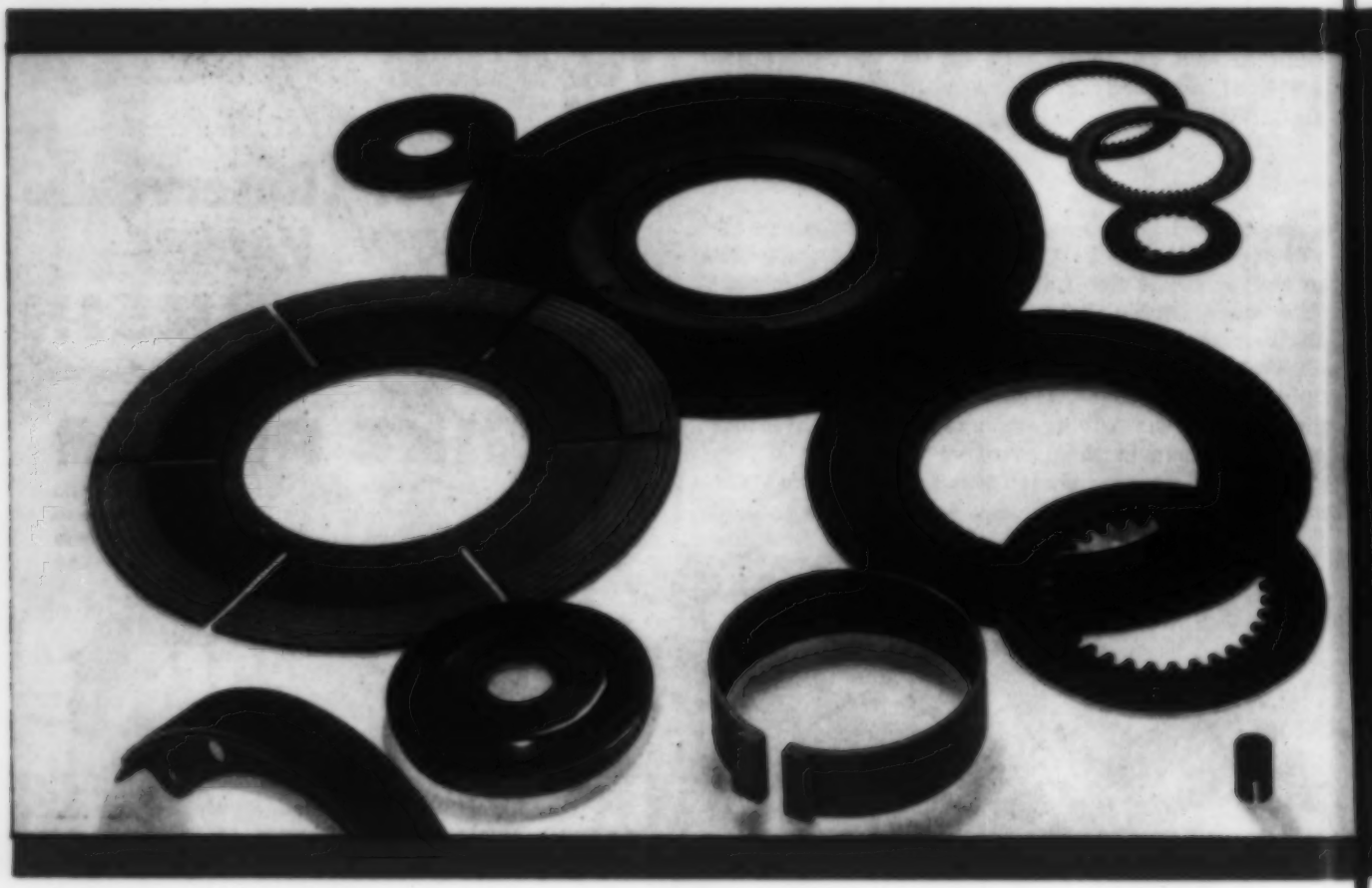

HOW R/M CAN HELP IN BONDING FRICTION MATERIALS

The bonding of friction materials to other mating members is an art. R/M has spent more years than any other company acquiring proficiency in it. Each successive job we've tackled has added to our knowledge of friction materials behavior. And trouble-shooting field trips—hundreds and hundreds of them—have familiarized R/M engineers with countless bonding problems. So the chances are good that if one is confronting you now, R/M has already solved it.

R/M can bond to almost any type material. Steel is most frequently used. But R/M can also bond to aluminum, phosphor bronze, and fibrous materials.

Unlike other manufacturers, R/M works with *all* kinds of friction materials—offers you the widest range in the industry. Consequently you can be sure of completely unbiased advice when you consult an R/M engineer.

If you feel that friction-parts performance could be improved in your equipment, contact Raybestos-Manhattan now. All the depth and breadth of R/M experience—the complete facilities of R/M's seven great plants with their research and testing laboratories—is as near as your telephone.

Write for your copy of R/M Bulletin No. 500. It's loaded with practical design and engineering data on all R/M friction materials.

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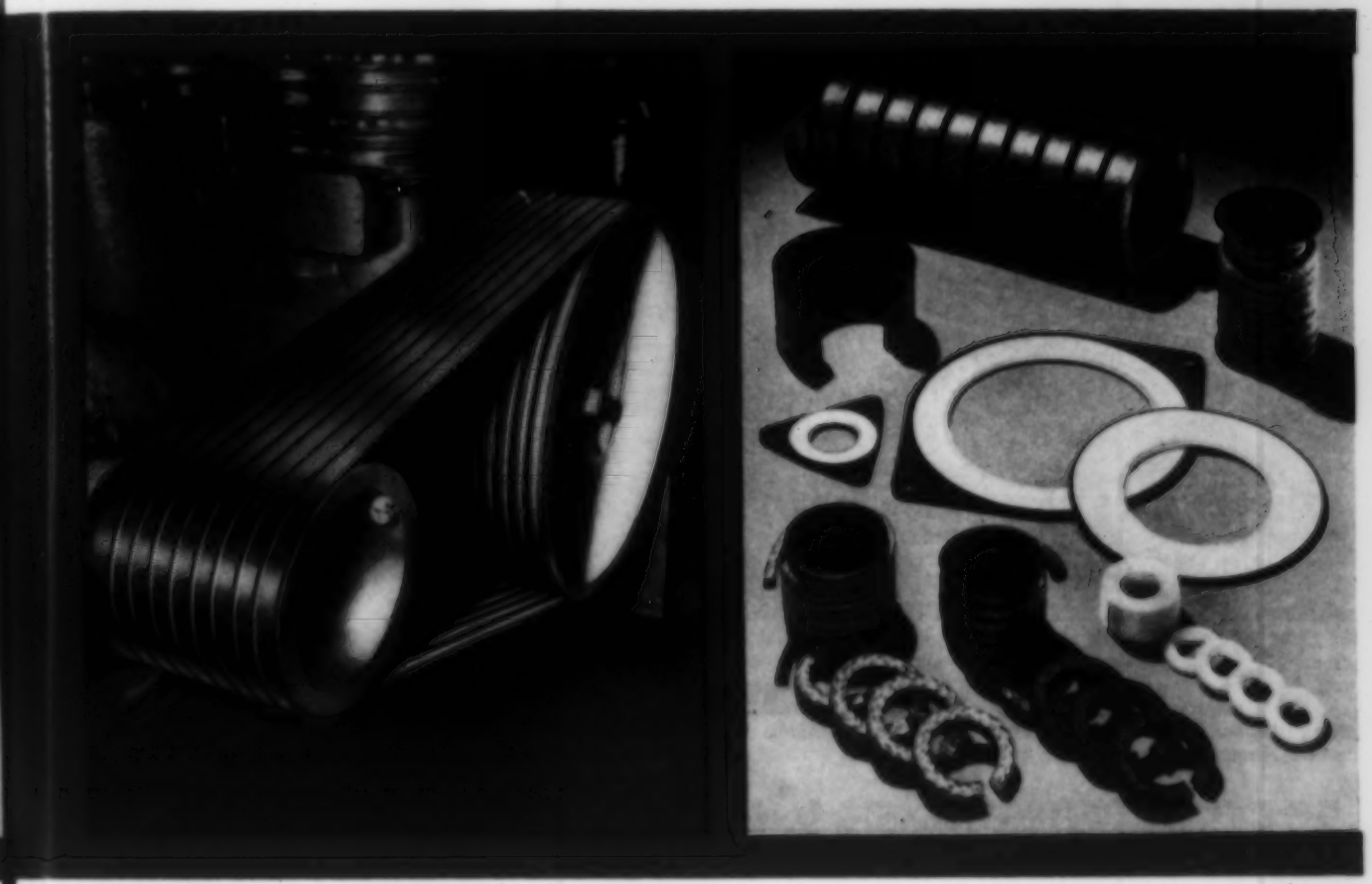

R/M SUPER-POWER V-BELTS

With R/M Super-Power V-Belts you obtain up to 40% greater horsepower capacity over the same number of regular V-belts. You can save space, as fewer belts are required. In addition, there is virtually no stretch and practically no matching problem. Made with new high strength synthetic cords. Straight sidewalls provide more grip, less slip, longer life. R/M Super-Power V-Belts are also oil-proof, non-spark, and heat-resistant. Bulletin 6628 contains details. Of course, Condor V-Belts continue to be the standard for regular service.

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PACKINGS, GASKETS, Asbestos Textiles and "TEFLON"* products

If you have a packing problem, don't hesitate to call on R/M's specialized packing engineering service. R/M has the right type of engineered packing or gasket sheet, no matter what you are sealing: air, gas, water, steam, oil, solvents, foods or hydraulic fluids. Consult R/M also if your requirements call for asbestos textiles or "TEFLON" products. Take full advantage of R/M's many years of experience in all of these fields. Write for booklet on packings, gaskets and "TEFLON" products.

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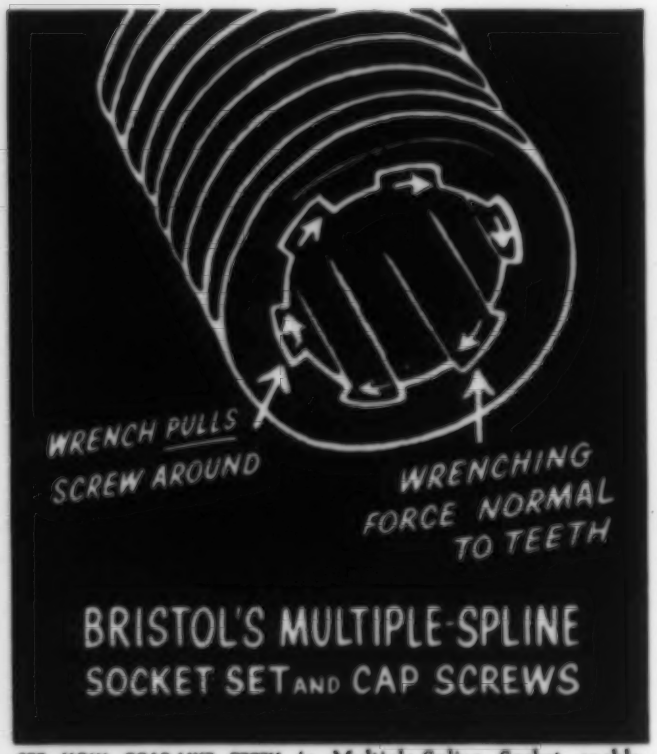


SEE HOW GEAR-LIKE TEETH in Multiple-Spline Socket enable wrench to *pull* screw around. No expanding pressure – *all* wrenching force is translated into rotary motion. Result: faster assembly, tighter wrenching for greater holding power. Bristol's Multiple-Spline Socket Screws can be wrenched thousands of times and never break or round out at high torque.

BETTER TWIST in socket screws — from elementary engineering principle

We're talking about the multiple-spline – you probably discussed it in your first year at engineering school.

It was this age-old principle, recognized as one of the best means of transmitting rotary power (used on automobile drive shafts, rear axles and airplane propeller hubs, for example), that Bristol's design engineers thought of when they set out to build a *better* socket screw.

Here's what they discovered: internally splining the socket of an ordinary socket screw produced a screw that would never split or round out, yet have more "wrenchability" and hold tighter than any other screw.

That's the story behind the Bristol Multiple-Spline Socket Screw – now used wherever shock and severe vibration exist . . . wherever a *better* socket screw is needed.

If you're not already familiar with these extra-strong fasteners, we'll be glad to mail samples to you. Tell us the size and type you want (Bristol's Multiple-Spline Socket Screws are made in sizes from No. 0 wire to ½ inch – cap and set).

A.4.12

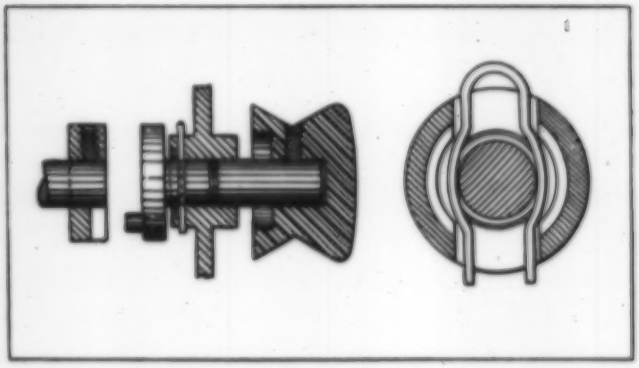
BRISTOL'S SOCKET SCREWS

THE BRISTOL COMPANY, Socket Screw Division, Waterbury 20, Conn.

Noteworthy Patents

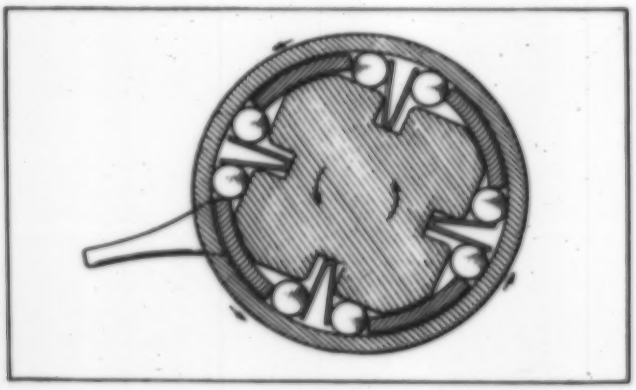
(*Continued from Page* 323)

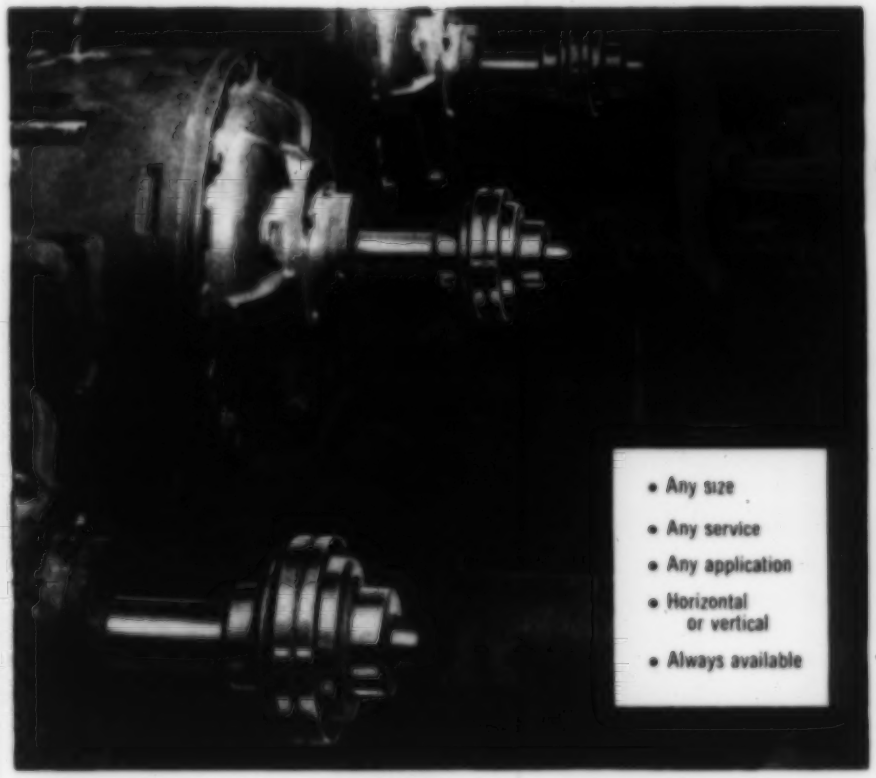
or disengaged position by means of grooves in the shaft and a specially mounted detent spring. Pulling the knob out disengages the drive and locks the shaft in the disengaged position. Conversely, the shaft is locked in the engaged position when pushed in. Dis-



connection of the drive is possible without disturbing the angular position of the drive shaft. Components driven by the shaft may be removed from the chassis without disassembling the indicator mechanism. Easy engagement and operation are possible despite slight angular misalignment between the drive and driven shafts. *Patent* 2,684,142 *assigned to Hoffman Radio Corp. by L. A. Willyard and J. W. Daniels.*

TWO-WAY OVERRUNNING CLUTCH utilizes rollers subjected to wedging action. Clockwise rotation of a hollow cylindrical driven member locks a set of rollers between the inner surface of the cylinder and flat surfaces of an inner driven shaft. Counterclockwise rotation wedges another similar set of rollers between the shafts to engage the clutch in that direction. Disengagement is controlled by pin stops set to actuate release fingers after a predetermined amount of rotation of the driven shaft. *Patent* 2,681,718 *assigned to Protair Corp. by E. M. Stoner.*





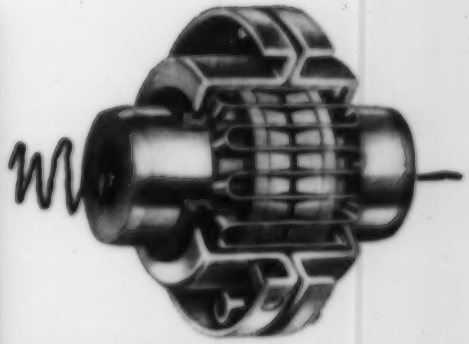
FALK Steelflex Couplings save you money by prolonging the work-life of connected machinery

Ever since the first Falk Steelflex Coupling was designed and built, more than thirty years ago, we have firmly held to these beliefs:

1. A coupling, to give fullest value, must do more than merely connect driving and driven machinery—it must protect the machinery and prolong its life.
2. A coupling, to be truly flexible, must overcome the effects of shock and vibration, as well as shaft misalignment (see column at right).

Proof of the soundness of these beliefs is furnished by the record. Many Falk Steelflex Couplings installed 10, 20, even 30 years ago are still giving trouble-free service—still providing maximum protection for the machinery they connect!

A single basic type—the world-famous Type F—fills nine out of ten industrial application needs. Versatile, efficient and economical, it is always quickly available, in a wide range of sizes, regardless of your location. Write to Department 247 for engineering bulletin, including selection and dimension details.

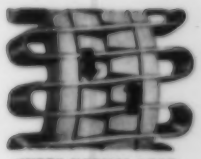


How Torsional Resilience smothers shock and vibration

The steel gridmember connecting hubs fits snugly only at outer edges of tapered hub-teeth. As load increases, gridmember flexes against teeth in proportion to load, providing cushion that spreads peak loads over longer time increment and reduces stresses in machinery.

...Accommodates shaft misalignment... Permits free end float

The exclusive FALK all-steel grid-groove design provides compensation for parallel and angular shaft misalignment . . . permits free end float.



UNDER NORMAL LOAD

ANGULAR MISALIGNMENT

PARALLEL MISALIGNMENT

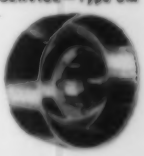
FREE END FLOAT

Special or Dual Purpose FALK Steelflex Couplings for problem applications

LIMITED SPACE
Type FS

RAPID REVERSING SERVICE—Type CM

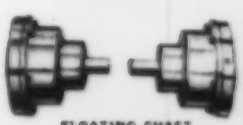
HIGH SPEEDS
Types H and HH



BRAKEWHEEL SERVICE
Type BW

OVERLOAD CONTROL
Type FT

EXTENDED SHAFT
Type P



FLOATING SHAFT
Type PP

Do you have a coupling problem?

If so, describe it in writing—we will gladly recommend the proper Steelflex coupling for your needs. Write to Department 247.

THE FALK CORPORATION, Milwaukee 8, Wisconsin

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HOKE

FLUID CONTROL SPECIALISTS

can solve your problem with all types and sizes

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for high vacuum conditions, high pressure conditions, and corrosive fluids

✓ **TEST & LABORATORY EQUIPMENT** Needle valves with chrome or nickel finish; quick-opening valves for stopcock service; ball-type check valves in brass and stainless steel; high vacuum valves in toggle style, packless and needle types.

✓ **CORROSIVE FLUIDS** Needle valves and toggle valves in several types of stainless steel; needle valves made from other alloys; aluminum, Monel, carbon steel; packless valves of diaphragm and bellows types in several alloys.

✓ **INSTRUMENT AIR LINES** Needle valves for direct panel mounting; toggle valves for on-off service with colored plastic handles for quick identification; valves for use with tube fittings.

✓ **SPECIAL DESIGNS** In many cases, our engineers can adapt standard valves to equipment manufacturers' special requirements.

Write for the Hoke Catalog

This completely illustrated 68 page catalog contains specifications on needle valves of all sizes as well as toggle valves, packless valves, special purpose valves, fittings and accessories. Tell us about your problem and we will gladly send you a copy of the catalog with our specific recommendations.

HOKE

HOKE INCORPORATED

Fluid Control Specialists

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New Machines

Metalworking

Horizontal Broaching Machine: Designed to broach boring bars up to 8 in. in diameter and up to 1¼ in. square, any length, horizontal broaching machine is readily adaptable to many other precision broaching applications, especially those where internal broached surfaces must be located in parts with irregular outside contours. Machine base is of I-beam construction. Follower and pull-head of the ram are of fixed-in-line centers and are guided on hardened and ground steel ways. Work table, which is raised or lowered to suit operation in line with fixed center of machine, can also be rotated to any position up to 45 deg. Broaches are guided and held in position to any angle required by the follower. A floating puller, of ball and roller bearing construction, allows succeeding passes to float accurately into position, or it can be locked rigidly. *Sturdy Broaching Service, Detroit, Mich.*

Pin Cutter: High-speed machine cuts pins from ⅛ to 3/16-in. diameter wire in lengths from 7/16 to 4¾ in. at speeds from 18,000 to 75,000 per hour. Accuracy of length is held to ± 0.0025-in. Ends of pins do not require deburring. Driven by a 3-hp electric motor, machine has a straightening arbor to straighten the stock as it enters, and an adjustable micrometer stop for length. It can be changed from one size wire pin to another in 10 minutes. *L. R. Brown Mfg. Co., New Haven, Conn.*

Punch Press: Designed for multiple and maximum stamping production and drawing up to 6-in. stroke, 50-ton Multi-Max punch press has 16 by 36-in. bed area. Ram area is 10 by 36 in.; shut die height, 10 in., with maximum shut die height to order, 24 in. Press operates at speed of 70 strokes per minute. Ram adjustment is 2 in. Press is of straight-side, twin-column design, underneath double-crank drive, back geared with herringbone heat-treated alloy steel gears. Clutch equilibrator and balance provides easy clutch engagement and disengagement and prevents falling of the ram with the use of large and heavy dies. *Diamond Machine Tool Co., Pico, Calif.*

Solid Die Header: Double-stroke header is built in both long and short-stroke models, the crankshaft throw being the only difference in construction. Long-stroke machine produces both long and short work at the rate of 80 blanks per minute. Maximum blank capacity is equal to a blank ½-in. in diameter and 6 in. long under the head. Maximum length of wire cutoff is 8 in. Short-stroke machine operates at a rate of 100 blanks per minute, the maximum blank capacity equal to a blank of ½-in. in diameter and 3½ in. long under the head. Maximum length of wire cutoff is 5½ in. Wire is fed from coil by a positive roll feed to the cutoff, which consists of a pair of thick blades held in slides. Wire blanks are

as a semi-finished part

For many end product uses B&W Mechanical Tubing —carbon, alloy or stainless—is already semi-finished. Finish machining is often the only manufacturing step involved.

The simplicity with which B&W Mechanical Tubing is integrated into many different manufactured products is evident because B&W tubing is produced with the particular end use application in mind. Users of B&W Mechanical Tubing therefore benefit from reduced handling costs, machining time and scrap loss.

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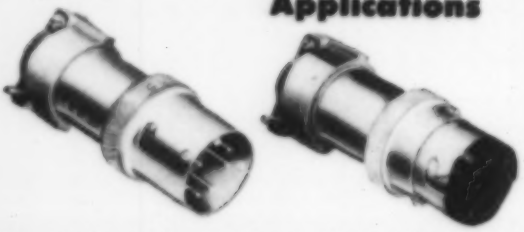

Wherever the modern trend toward automation requires fully automatic product and process control, R & S Ever-Lok multi-circuit plugs, receptacles and connectors provide a happy ending for cord connecting problems. These rugged, dependable automatic-locking multi-circuit devices are quality engineered to carry full-rated load currents safely and easily under the most severe operating conditions.

Write for Sales Data Sheet 1355-72

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FOR SOUND AND CONTROL EQUIPMENT

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PRECISION-BUILT ELECTRICAL EQUIPMENT—SINCE 1902

New Machines

then transported from the cutoff slides to the heading die by an independent transfer mechanism. After being headed, blanks are ejected from heading die by a knockout mechanism. Punch knockout, timed ejector and knockout relief mechanisms can be supplied for heading special shapes. *Waterbury Farrel Foundry and Machine Co., Waterbury, Conn.*

Wire Straightener and Cutter: Square or hex wire, $\frac{3}{16}$ to $\frac{1}{4}$-in., or flat wire $\frac{1}{16}$ x $\frac{1}{4}$ in. to $\frac{3}{32}$ x $\frac{1}{2}$-in. is straightened and cut automatically on model 2ABF Shuster straightener. Multiple sets of precision straightening and feeding rolls handle the wire easily and uniformly. Instantaneous clutch and cut-off assures accuracy in cutting predetermined lengths of wire. Machine incorporates ball and roller bearings, V-belt motor drive and automatic controls. *Mettler Machine Tool Inc., New Haven, Conn.*

Processing

Descaler: Hydra-Jet descaler removes scale from the surface of hot steel bars and billets which have been heated preparatory to forging or hot pressing. Oil hydraulics are employed to actuate a compound piston which instantly pressurizes water up to 2000 psi. The pressurized water is free of air inclusions and is directed to the hot metal surface through a cone ring orfice in an inverted spray cone pattern. Dense spray of water directed over a small area results in minimum temperature drop in the hot metal. Forging temperature can be closely controlled. Scale removal is complete, and the finished product has a surface free from scale pits. Less than one quart of water is required to descale 18 inches of a 3-in. bar. Capable of handling stock up to 3 in. in diameter, the machine occupies 2 x 12 ft of floor area. It can be supplied for either push-back or push-through type operation and with controls which are manual, automatic or a combination of both. *Commercial Shearing & Stamping Co., Youngstown, O.*

Fluxless Solderer: New model of Sonobond, ultrasonic equipment for fluxless soldering of aluminum, copper, brass, silver and magnesium, consists of an ultrasonic generator, heating platen and a hand-operated soldering head. Model No. S-3-H-54-11 is adapted to hermetic sealing, electrical wire joining and other moderate-size work. It accommodates soldering tips from 3/16 to 5/16-in. diameter. It will tin aluminum in 3 to 5 seconds. *Aeroprojects Inc., West Chester, Pa.*

Die-Casting Machine: Model HP-2½X-SF is designed to cast up to 6¾ lb of aluminum or proportionate weights of magnesium or brass. In the shot assembly, machine provides 21,000 psi maximum pressure on metal. Both shot speed and pressure are adjustable. Two fixed shot positions are provided. Four hundred tons of preload clamping is made possible by one-piece alloy steel frame with beam area equal to 6½-in. tie bars. This frame also assures permanent parallel alignment of the platens. Die opening is 12 in. Movable platen is 28 in. wide, with a vertical clearance between the beams

of 26 in. An 18½ x 52⅝ in. opening in the top of the frame provides accessibility to die space from all sides. Pumping system of the machine uses a 20-hp motor and includes a 2000-lb booster pump. Timed casting ejection is provided by the central hydraulic ejector. *Lester-Phoenix Inc., Cleveland, O.*

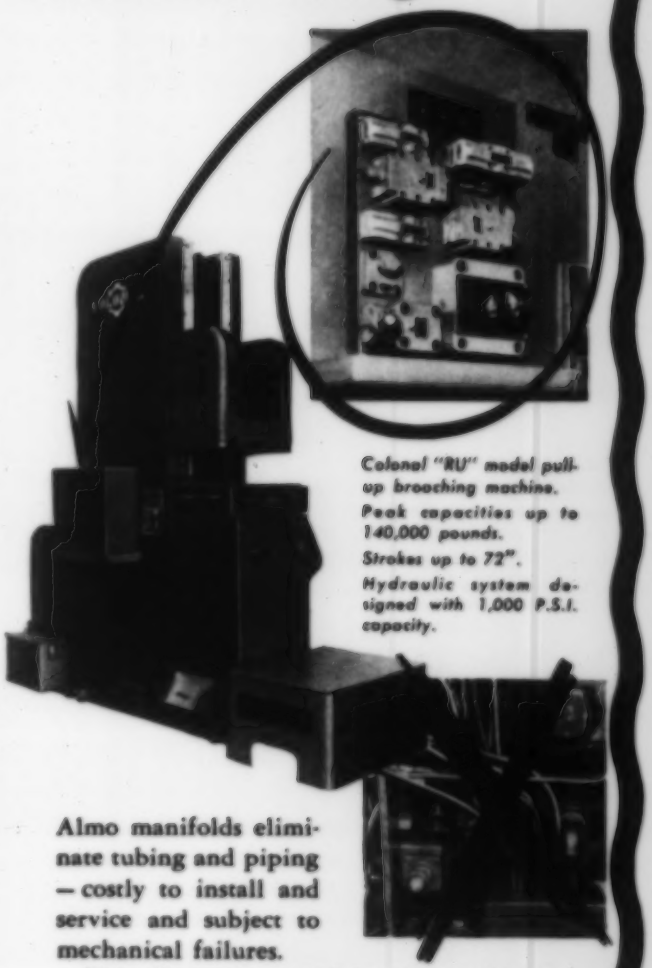
Gear Surface Hardeners: Two new gear surface hardeners have sensitive electronic controls. Oxyacetylene flames traverse each tooth separately; a sensitive radiation pyrometer focused on the tooth receives radiant energy from the hot metal and an electronic balancing mechanism translates that energy into forces which control the travel of the burners along the tooth. Operation is automatic after optimum hardening temperature has been preset and the machine has been started. In normal operation, machines are indexed so that the teeth hardened successively are not adjacent, eliminating the possibility of a change in bore diameter during hardening. Machines are readily adaptable to surface hardening teeth of straight bevel, spiral bevel, Zerol, spur, herringbone, or helical gears. Model No. 1 accommodates bevel gears up to 24-in. pitch diameter, spur and helical gears up to 30-in. pitch diameter, and internal gears up to 24-in. OD. The No. 2 machine can be used for gears up to 120-in. pitch diameter. *Gleason Works, Rochester, N. Y.*

Testing and Inspection

Spring Tester: Designed for fast, accurate testing of tension, compression or leaf springs, new spring testers can also be used for checking the force required to engage or disengage mating subassemblies and components. They determine correct loads, tolerances and gradients. Design employs rigid levers, damped oscillation and automatic chart indication of spring force by means of a self-compensating pendulum weight with a sturdy arbor press type arrangement for applying spring loads. Two models, with maximum force capacities of 15 and 50 lb, will accommodate springs up to 3 in. in diameter and 12 in. long in compression. A locking device is provided for presetting spring length when testing a quantity of springs of the same length. Wide range of standard models is available with sensitivities from ¼-gram. *Pennsylvania Scale Co., Bareville, Pa.*

Gear Classifier: 3-Way classifier separates gears into acceptable, salvageable and nonsalvageable categories. Classification is based on any one or a combination of the following gear sizing factors: undersize, oversize, correct size, eccentricity, and plus or minus helix angle. Conveyor type classifier handles wide-face and cluster gears. Gears enter from the left side on a continuous belt conveyor with gear face perpendicular to the line of conveyance. When a discrepancy in a gear occurs, the unit's master gears provide the signal source that actuates the corresponding rejection gate, and the gear is swept into the salvageable or nonsalvageable chute. Classifier will turn off a gear-producing machine if it makes consistent errors. *Michigan Tool Co., Detroit, Mich.*

how ALMO hydraulic control manifolds contribute to better machine design



Colonel "RU" model pull-up broaching machine.
Peak capacities up to 140,000 pounds.
Strokes up to 72".
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Almo manifolds eliminate tubing and piping — costly to install and service and subject to mechanical failures.

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